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USER GUIDE

Standard HVAC Control Systems Commissioning and Quality Verification User Guide

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CONTENTS

1 INTRODUCTION

This document serves as a guide to quality verification (QV) personnel, inspectors, and other personnel who are involved with seeing that the standard heating, ventilating, and air-conditioning (HVAC) control systems, as specified in the U.S. Army Corps of Engineers (USACE) Guide Specification (CEGS) 15950, are installed and commissioned correctly. This user guide is based on CEGS 15959 (July 1990 version), including the changes made up through December 1992.

QV personnel should use the information presented here to learn more about control systems so they can make informed decisions about whether or not a contractor has met the requirements of the specifications. Hopefully, QV personnel will find the checklists provided here useful, and will copy them for use in Achecking out@ the control system design, submittals, and equipment.

The commissioning procedures and report, and performance verification procedures and report are given as examples of what a contractor would ideally provide. Electronic versions of these files are available bY contacting Glen Chamberlin, U.S. Army Construction Engineering Laboratories (USACERL) 217-373-7238, 800-872-2375 x7238, or Fax 217-373-6740.

Changes to CEGS 15950 and Technical Manual (TM) 5-815-3 will likely occur, so the user of this document will need to change some of the checklists. If the interest and need arise, this document will be updated in the future.

There are two 1-week courses currently available to Corps personnel that cover the standard HVAC control systems: PROSPECT course number 340, which deals with design, specification, and construction; and PROSPECT course number 382, which deals with commissioning and quality verification. If necessary, an operations and maintenance course will be developed.

For further information, refer to the other user guides included here: *Standard HVAC Control Systems Retrofit Design*, for information about retrofit design, and *Operation and Maintenance of Standard HVAC Control Systems*, for details about operations and maintenance.

While this user guide specifically applies to standard HVAC control systems, many of the checklists and information are transferable to whatever HVAC control system is being installed.

The following people can be contacted for additional information and comments.

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2 BIDDABILITY, CONSTRUCTABILITY AND OPERABILITY (BCO)/DESIGN REVIEW

GENERAL

This section deals with conducting BCO/Design Reviews of standard HVAC control systems. BCO Review is a term used by the Corps District offices and is essentially meant to mean a review of the design by the Field Offices to determine if what has been designed is complete, can be made, and will work. A Directorate of Public Works (DPW) will probably not have a Field Office but someone, or a group of people should review the design. The QV personnel can use the BCO/Design Review Checklist to perform their review, or in the absence of any design reviewers, the designer could use the Checklist to review their work.

OVERVIEW OF BCO REVIEW

Historically, from the field office perspective, HVAC control systems on Corps projects have received little or no attention until the contractor begins providing the Government with submittal data. With the standard HVAC control systems, the QV personnel will now review the Design/Contract Package that the designers have put together.

QV personnel should review the design to ensure that it conforms with the intent of the Technical Manual and Guide Specifications. For a specific type of system, the design drawings should be the same from system to system and should conform to the Technical Manual drawings for that system type. If the system is modified, special attention must be given to verify that requirements of the specifications and drawings are coordinated.

It should be found that the effort expended in the BCO review will be rewarded by a reduction of effort expended during submittal review, installation inspection, commissioning, and performance verification testing of the systems. In addition, uniformity in the control systems will be maintained and a properly operating system is more likely to be delivered to the user. Finally, even though efforts are being made to train Corps of Engineers designers, many AE designers have not been trained. Depending on the experience level of the designer, mistakes might be made that experienced QV personnel could spot in the review process.

During an actual BCO Review, the specifications, calculations, and design analysis should also be reviewed. The specifications should generally require little editing, but should be reviewed to ensure that the drawings and specifications are consistent. If any modifications to the standard design are made, they should be clearly indicated and a brief discussion explaining why the deviation is necessary should be included.

BCO REVIEW CHECKLIST

I. SPECIFICATIONS

A. REDUNDANCY. Check for, and eliminate, any redundancy in specifying the following equipment in other sections of the specification:

1. Control air dampers
2. Automatic control valves
3. VAV terminal unit controllers
4. Control system air compressors
5. Thermostats
6. Pressure gauges
7. Temperature gauges
8. Time clocks

B. TEST REPORTS, SD-70

1. Number of copies for Site Testing Procedures noted.
2. Number of copies for Site Testing Data noted.
3. Number of copies for PVT Plans and Procedures noted.
4. Number of copies for PVT Report noted.

C. OPERATION AND MAINTENANCE MANUALS, SD-80

1. Number of copies for Operation Manuals noted.
2. Number of copies for Maintenance Manuals noted.

D. OPERATING INSTRUCTIONS, SD-81

1. Number of copies for Commissioning Procedures noted.

E. RECORDS, SD-91

1. Number of copies for Commissioning Report noted.

F. REPAIR REQUIREMENTS, SD-85

1. Number of copies of Service Organizations noted.

G. SEQUENCE OF OPERATION (CONTROL LOGIC)

1. Section 3.3, CEGS 15950 version of the Sequence of Operation has been included in the contract specifications for each system.
2. The Sequences of Operation are consistent with the drawings and any modifications to the standards have been incorporated.

H. COMMISSIONING PROCEDURES

1. Section 3.4, CEGS 15950 version of the Commissioning Procedures has been included in the Contract specifications for each system.
2. The Commissioning Procedures are consistent with the drawings and any modifications to the standards have been incorporated.

II. DRAWINGS

A. Confirm that the following drawings have been included in the contract.

1. TM Fig. 4-xxA, Control System Schematic (Note 1)
2. TM Fig. 4-xxB, Control System Ladder Diagram
3. TM Fig. 4-xxC, Control System Equipment Schedule
4. TM Fig. 4-xxD, Interior Door Layout for HVAC System Control Panel, Interior Door Layout for HVAC System Control Panel (Rear View), Switch and Pilot Light Legend
5. TM Fig. 4-6C, Interior Door Layout for HVAC System Control Panel, Interior Door Layout for HVAC System Control Panel (Rear View), Switch and Pilot Light Legend, Standard Controller Cutout (Note 2)
6. TM Fig. 4-xxE, Back Panel Layout for HVAC System Control Panel
7. TM Fig. 4-6D, Back Panel Layout for HVAC System Control Panel, Section B-B (Mounting Rail Dimensions) (Note 3)
8. TM Fig. 4-xxF, Control Panel Terminal Block Layout
9. TM Fig. 4-6A (note 4)
10. TM Fig. 4-6B, Section A-A (Side View) of Control Panel
11. TM Fig. 4-6F, Controller Wiring (Note 5)
12. TM Fig. 4-6G, Supply and Return Fan Starter Wiring, where applicable
13. TM Fig. 4-6H, Exhaust Fan Pump Starter Wiring, where applicable
14. TM Fig. 4-6I, HVAC Control Panel Power Wiring
15. Reset Schedule, where applicable
16. Space Temperature Control Schedule, where applicable

Note 1. Axx@ refers to the drawing series number.

Note 2. The preferred method is to transfer information from TM Fig. 4-6C to TM Fig. 4-xxD, and eliminate TM Fig. 4-6C.

Note 3. The preferred method is to transfer information from TM Fig. 4-6D to TM Fig. 4-xxE, and eliminate TM Fig. 4-6D.

Note 4. TM Fig. 4-6A, Side View, can be eliminated if the panel dimensions and panel clearance are shown on other drawings. The Front View should remain for noting Section A-A location.

Note 5. Modifications may be required, depending on the application.

III. DRAWING DETAILS CHECK

A. Control System Schematic

1. System number added to Unique Identifiers

B. Control System Ladder Diagram

1. System number added to Unique Identifiers

2. EMCS input and output connections shown, when applicable
   Inputs: Time clock, Vent Delay, Economizer
   Outputs: Economizer, Filter, Low-Temp alarm, Smoke alarm
3. Remote Safety Shutdown input from fire alarm system, when applicable
4. Remote Safety Override input, when applicable

C. Control System Equipment Schedule. The Equipment Schedule should reflect system-specific parameters calculated and selected by the designer. The TM Equipment Schedule drawing for each system shows example values for each of these system-specific parameters. Ensure that the design is complete by checking to see that the designer changed the example values and provided other necessary information to reflect system-specific requirements:

1. System number(s) added to Unique Identifiers
   (i.e., VLV-XX01 6 VLV-0101)
2. Other Unique Identifier information provided
   (i.e., SPACE-XXXX 6 SPACE/ROOM 0114, FTR-XX 6 FTR-01)
3. Minimum outside air CFM included and consistent with AHU schedule
4. Valve C_v values
5. Valve close-off pressure
6. Thermostat and aquastat setpoints
7. Controller setpoints
8. Economizer controller PV and DEV contact open/closed temperatures
9. Outside Air Temperature Aproportional-only@ controller configuration parameters:
   - Reset Schedule calculation results:
     - Setpoint, EF
     - Proportional Band, %
     - Maximum Output, %
     - Manual Reset, %
   - Process variable (PV) contact:
     - HW Pump start/stop temperatures
10. Other Aproportional-only@ controller configuration parameters:
    - Proportional Band, %
    - Setpoint, EF or %RH
    - Manual Reset, %
      - Maximum and minimum setpoint limits, where applicable
11. Return Fan Volume controller configuration parameters:
    - Range (controller Scaling) = flow transmitter fpm x duct area
    - Ratio = see TM Equation 3-2
    - Bias = Minimum outside air setting
12. Temperature setpoint device range
13. Transmitter ranges must be consistent with specifications
    - Temperature, pressure, humidity, air flow
      - (Note: air flow transmitter range is shown as CFM. Transmitter range is FPM - controller scales signal to convert to CFM)
14. Clock schedule
15. Night setback schedule

D. Back Panel Layout for HVAC System Control Panel
   1. Same as TM drawing
   2. System numbers added to Unique Identifiers

E. Section A-A (Side View) of Control Panel
   1. Same as TM drawing

F. Section B-B (Mounting Rail Dimensions)
   1. Same as TM drawing

G. Interior Door Layout for HVAC System Control Panel
   1. Same as TM drawing
   2. System numbers added to Unique Identifiers

H. Interior Door Layout for HVAC System Control Panel (Rear View)
   1. Same as TM drawing
   2. System numbers added to Unique Identifiers

I. Control Panel Terminal Block Layout
   1. Same as TM drawing
   2. System numbers added to Unique Identifiers

J. Switch and Pilot Light Legend
   1. Same as TM drawing
   2. System numbers added to Unique Identifiers

K. Standard Controller Cutout
   1. Same as TM drawing

L. Reset Schedule (where applicable)

M. Space Temperature Control Schedule (where applicable)

IV. ADDITIONAL CHECKS OF DRAWINGS

A. Electrical circuit for compressed air station identified on panel schedule.

B. Air flow station identified on ductwork layout drawings.

C. EMCS drawings indicate that the standard HVAC control system transmitter ranges are used for the EMCS also.

D. The method of fan modulation is consistent between control drawings and Air Supply and Distribution specification.

E. Fan schedules for the air handling units are consistent with the control drawings.

F. The static pressure sensors are properly located on the duct work layout.

G. If high efficiency filters are specified in other sections of the specifications, the control drawings should reflect the requirement of an additional differential pressure switch and differential pressure indicator. The differential pressure switch should be shown on the ladder diagram to be interconnected with the filter pilot light.

H. If humidifiers are specified control drawings should reflect the type specified.

I. Confirm that ladder diagrams reflect any modifications made from the standards, and are consistent with the sequence of operation.

J. If pneumatic actuators are indicated on the drawings, confirm that a compressed air station is specified and shown or a source of compressed air is shown.

K. If compressed air is provided by other than the compressed air station, confirm that the compressed air source has an air dryer and filters specified.

L. If smoke dampers are used, confirm that they are indicated on the control schematics, specified in the control specifications and indicated on the ductwork layout.

M. If exhaust fans, unit heaters, ventilation dampers, or other system devices are used that are considered to be a Avariation@ from the standard system, confirm that they are incorporated into the System Schematic, Sequence of Operation, Equipment Schedule, Ladder Logic Diagram and other system drawings.

N. Confirm that the location of the outside air sensor is noted on the drawings.

O. If air flow stations are used, confirm that they are shown on the ductwork layout, and that adequate lengths of straight duct runs are provided before and after the flow station.

P. Confirm that adequate space has been provided for the control panel.

Q. Confirm that the ranges of the pressure gauges for hydronic systems are indicated on the drawings.

3 COMMON SETPOINTS FOR HVAC SYSTEMS

GENERAL. A setpoint defines the value of a process variable that a control loop is to maintain. Typical process variables controlled by HVAC systems are temperature, pressure, air volume, and humidity.

PREHEAT COIL DISCHARGE AIR TEMPERATUREC40 to 55E F.

COOLING COILC55 to 60E F: The cooling coil's setpoint depends on the type of air-side system being used (variable air volume [VAV], Multizone, etc.) and various coil selection parameters. For VAV systems, lower cooling coil discharge air temperatures result in space loads being satisfied by lower air flow rates.

HEATING COILC80 to 95E F: The heating coil's setpoint depends on design parameters and is often reset as a function of outside air temperature.

MIXED AIR TEMPERATUREC52 to 58E F: The mixed air temperature setpoint is 2 to 3E F below the cooling coil's discharge air temperature. This compensates for the temperature rise across the supply fan (for blow-through units) and ensures that the cooling coil valve is fully closed when the outside air temperature is low enough to satisfy the space cooling loads.

MINIMUM OUTSIDE AIR VOLUMEC The minimum outside air volume setpoint is based on the system's exhaust and ventilation air flow requirements. For VAV systems, the minimum outside air volume setpoint is based on the lower end of the supply fan's air volume range, which should equal the sum of the minimum air flow settings of all of the VAV boxes in the system. The controller is programmed with the minimum air volume setpoint in units of CFM.

RETURN AIR VOLUME FLOWC In VAV systems that use return fans, the amount of air that the return fan brings back from the zones is based on the supply air volume flow. As the supply air volume flow changes, the supply air flow station sends a signal to the return fan flow controller for resetting of the Apre-setpoint@ of the controller. The return fan flow controller subtracts (bias) a certain amount of cfm from the Apre-setpoint@ to establish the setpoint of the return fan flow controller. The volume (cfm) subtracted from the controller should be equal to the minimum outside air volume setting, in cfm.

SUPPLY DUCT STATIC PRESSUREC In VAV systems, the supply duct static pressure is used to control the air delivered by the supply fan. The setpoint of the static pressure sensor should equal the sum of the minimum static pressure required at the inlet of the VAV terminal units and the pressure loss in the ductwork between the sensor and the most remote VAV terminal unit at the maximum air flow rate. Typical supply duct static pressure setpoints are in the range of 0.8 to 1.5 inches of water gauge. During system balancing, the optimum setpoint can be established by lowering the setpoint value to the lowest possible setting at which the most remote VAV terminal unit will continue to function properly. At this setting, the minimum fan energy will be consumed. Note that the supply fan's volume can be varied by the use of inlet guide vanes or a variable frequency motor drive. Inlet guide vanes control a fan's capacity by imparting a spin on the air stream entering the fan scroll in the direction of the fan wheel's rotation. This rotation of the inlet air stream reduces the fan wheel's ability to Agrab@ the air. Variable frequency motor drives control the fan's capacity by varying the speed of the motor. A high limit static pressure sensor is often provided in the ductwork downstream of the supply fan to prevent damage to the ductwork in the event of a failure in the static pressure control loop.

HUMIDIFICATIONCRelative humidity (RH) setpoints are based on the environmental requirements of the space being served. Computer rooms and other critical processes generally require tight control on both the lower and upper ends of the RH range (commonly 45 to 55% RH). When humidification is provided for comfort applications, the minimum RH setpoint is 35%. In the event of a humidification system failure, a high limit RH sensor is provided downstream of the humidifier to limit the discharge RH. The output of the high limit RH sensor is received by a high limit relative humidity controller that has a setpoint in the range of 90 to 95% RH.

SPACE TEMPERATUREC For comfort control, the setpoint will be 70E F during the heating season and 78E F during the cooling season. The temperature range between these values is a deadband in which no heating or cooling occurs. For computer rooms, critical areas of hospitals, labs, etc., the temperature setpoint will commonly be maintained between 72 to 75E F year around.

NIGHT SETBACK TEMPERATUREC As an energy-saving feature for noncritical areas, air-side systems are shut down during unoccupied times. During the winter months, the space temperature within a building could fall below the freezing point. To prevent freezing temperatures in the zones during unoccupied times, a night setback thermostat is provided. The night setback thermostat setpoint is generally between 45 and 55E F, depending on energy conservation calculations or material storage requirements.

DRY BULB ECONOMIZERC The economizer cycle is controlled based on a comparison of the return air and outside air dry bulb temperature values. For the economizer cycle to operate, there must be a cooling demand as indicated by the return air temperature. If the return air temperature is above about 73E F, there is a probable demand for cooling. In addition to a cooling demand, the outside air must be cool enough to supply free cooling. At first, one might expect the economizer to function when the outside air temperature drops below the return air temperature. This approach fails to consider the fact that air at any given temperature can have a range of total heat content (or enthalpy) depending on the air's relative humidity. Unfortunately, it is very difficult to accurately and reliably measure the relative humidity. Therefore, it is necessary for the outside air temperature to be lower than the return air temperature by a difference great enough to assure that the enthalpy of the outside air is less than that of the return air. The designer must calculate an optimum temperature differential for the particular climatic location. Typical temperature differentials vary from 7 to 10E F. The method of obtaining the setpoints and temperature differential is explained in the calculation section of this guide.

4 HVAC CALCULATIONS

A. AIR COMPRESSOR SIZING CALCULATIONS

1. General. Compressed air stations are used to provide main supply air to the air consuming devices in an HVAC system. A basic air station consists of an air compressor and an air storage tank. In addition, there is an air pressure regulator, an air drier, and oil and dirt filters.

2. Air Compressor Criteria. The running time criteria for sizing an air compressor are as follow:

a. **Initial design**. The running time for an air compressor in an initial system design is not to exceed 33.3 percent. Thus, the delivered air capacity of the compressor must be at least three times the estimated air consumption of the HVAC system.

b. **System additions**. Air consuming devices may be added during modification or expansion of existing systems until the compressor running time reaches 50 percent.

3. Air Compressor Sizing Approach.

a. The approach that the designer should take in sizing the air compressor is to make an estimate of the total air volume required by the air consuming devices in the system based on the above stated criteria. The basic relationship to be used in sizing the compressor is:

$$T_r = \frac{Q_c \times 100}{Q_d} \qquad \text{Eq. 4-1}$$

where:

T_r = Air compressor running time
Q_c = Total air consumption in standard cubic inches per minute (scim)
Q_d = Air compressor delivery in scim

b. Specific air compressor sizing steps are as follows:

(1) Add up the air consumption of all air consuming devices shown on the schematics to arrive at the total air consumption (Q_c). Be aware that the air consumption ratings of some devices are given in standard cubic feet per minute (scfm) rather than standard cubic inches per minute (scim). The conversion is: scim = scfm x 1728.

(2) Substitute Q_c into Equation 4-1 to arrive at the minimum air delivery rating (Q_d) of the compressor. Using compressor manufacturer's literature, an estimate of the HP rating of the compressor can be made. Be advised that compressors often have

displacement and capacity ratings. The capacity rating is typically from 60 to 80 percent of the displacement rating.

4. **Storage Tank Requirements.** The air compressor's storage tank shall be fabricated to withstand a 200 pounds per square inch gage (psig) working pressure and sized so that the compressor needs to make no more than six starts per hour with the starting switch set for a 20 pounds per square inch differential (psid) pressure differential.

B. CONTROL VALVE C_v CALCULATIONS

1. **General.** Control valves are relatively simple devices that restrict the flow in a pipe. Control valves may be two-position or modulating and two-way or three-way, depending on the application. They can also be classified based on whether they are used in water or steam service applications. The Technical Manual provides guidance on what types of valves to use in each service application.

In addition to selecting the type of valve and service, the designer must determine and specify the valve's close-off pressure rating and its flow coefficient, C_v. C_v is defined as the flow rate through the valve, in gallons per minute (gpm) of 60° F water, that will give a pressure drop across the valve of 1 psid. The underlying principle in selecting a valve's C_v is that at the design condition it must be capable of passing the required water or steam to meet the system demand. At this design condition, the valve is fully open.

2. **Control Valve Authority.** An important consideration in sizing control valves is Valve Authority. The authority of the control valve is determined by its β-ratio, which is calculated as follows:

$$\beta = \frac{\Delta P_{Tot}}{\Delta P_{VLV}} \qquad \text{Eq. 4-2}$$

where:

ΔP_{Tot} = Pressure drop across the valve
ΔP_{VLV} = Pressure drop across the valve and the coil piping circuit

The valve should be selected so that β is no less than 0.5. This is illustrated in Figure 4-1.

The C_v of the control valve is based on ΔP_{Tot} since the valve must be sized according to the maximum flow that it is to control. Note that when the valve is nearly closed the actual flow through it will be higher than the theoretical flow due to increased pressure drop across the valve.

3. **Close-Off Pressure Rating.** The close-off rating indicates the pressure against which a valve must be able to close. Figure 4-2 is a typical normally open pneumatic valve. F1 is the force due to the control air pressure signal acting to close the valve. F2 is the opposing spring force and F3 is the force exerted by the fluid (water or steam). The value of F3 is actually due to

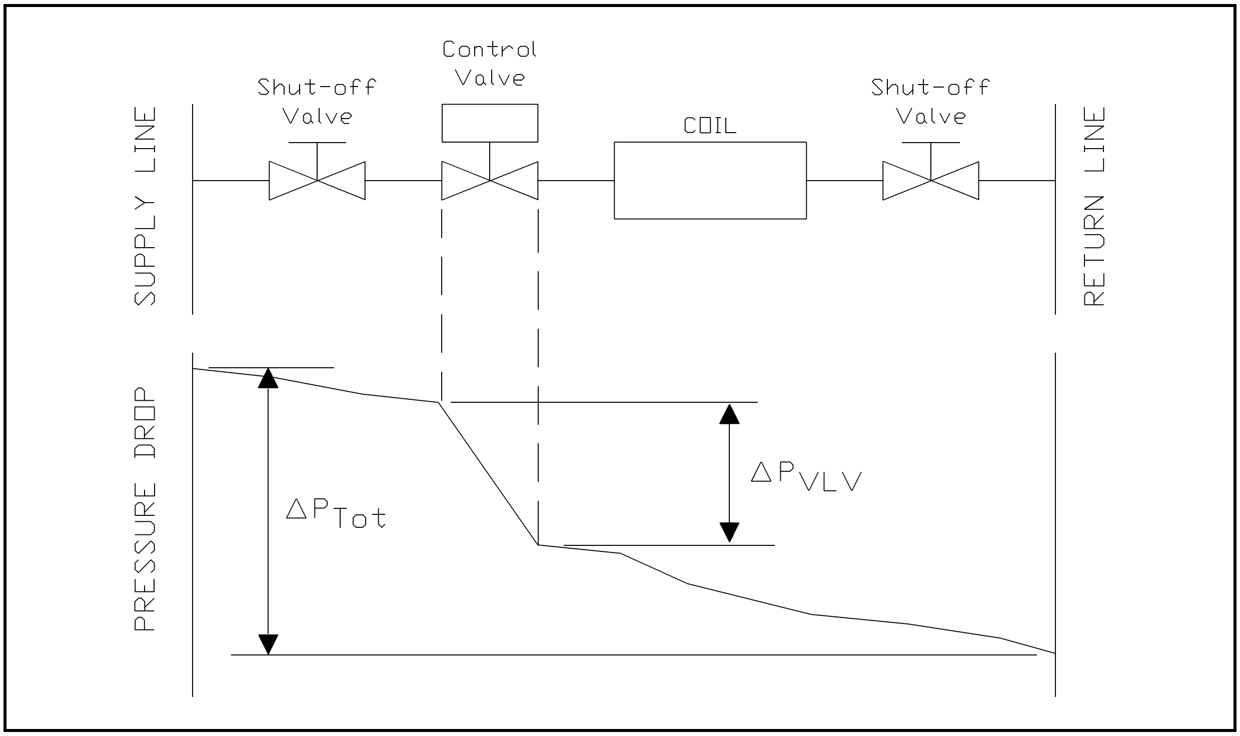


FIGURE 4-1. CONTROL VALVE PRESSURE DROP.

the difference in pressure on the two sides of the valve plug. The valve and actuator must be able to close the valve against fluid force F3. The expected value of F3 is part of the hydraulic design of the piping system and depends upon the location of the valve within the system. The pressure the valve must close against is normally specified at several times the value actually expected at the valve's location. A three-way valve must operate against a similar fluid pressure in moving from one position to another.

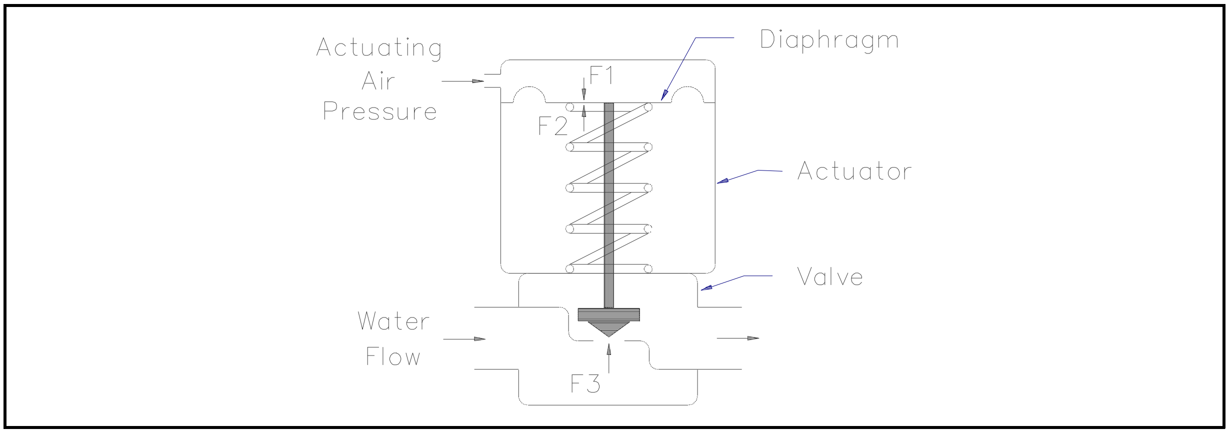


FIGURE 4-2. TYPICAL NORMALLY OPEN PNEUMATIC VALVE.

4. C_v Calculation for Liquid Service. For each liquid service valve, the capacity index or flow coefficient, C_v, must be calculated.

a. **Two-position valves**. For two-position valves, the valve will be line size with the largest available C_v. This will reduce the pressure drop across the valve and thus the pumping horsepower required.

b. **Modulating valves**. For modulating liquid service applications, C_v must be calculated for each valve. Before calculating C_v, the designer must consider cavitation. Cavitation is caused when the velocity through the valve creates an absolute pressure at the valve outlet that is below the vaporization pressure of the liquid. Cavitation can be prevented by placing an upper limit on the pressure drop across the valve. For the types of control valves specified for standard systems, this maximum allowable valve pressure drop can be found from:

$$\Delta P_{max} = K_m \times (P_e - P_v) \qquad \text{Eq. 4-3}$$

where:

ΔP_{max} = The maximum allowable pressure drop across the valve, psid.
K_m = Valve pressure recovery coefficient (Use 0.45).
P_e = The absolute pressure of the liquid at the valve inlet, pounds per square inch absolute (psia).
P_v = The absolute vapor pressure of the liquid entering the valve, psia.

The next step is to estimate the pressure drop through the valve necessary for good control. As a rule, the pressure drop across a valve at full flow should be greater than the pressure drop across the controlled circuit between the supply and return mains without the valve in the control circuit. This gives the valve the "authority" to control the given process. In the case of a heating or cooling coil, the controlled circuit would be the coil, the pipe, and pipe fittings as indicated between Points a and b in Figure 4-3. The circuit pressure drop occurs in a few short piping lengths, the coil, three tees, six 90° ells, and two shutoff valves. A heat exchanger circuit would be similar to the coil circuit with the pressure drop occurring in a tube heat exchanger, piping, and fittings.

Once the required valve pressure drop is determined, the C_v for a modulating control valve for liquid service can be found from:

$$C_v = \frac{GPM}{\sqrt{\Delta P / SG}} \qquad \text{Eq. 4-4}$$

where:

C_v = Valve flow coefficient.
GPM = Design flow through the valve in the fully opened position, gpm.
ΔP = Pressure drop through the valve, psid.
SG = The specific gravity of the liquid.

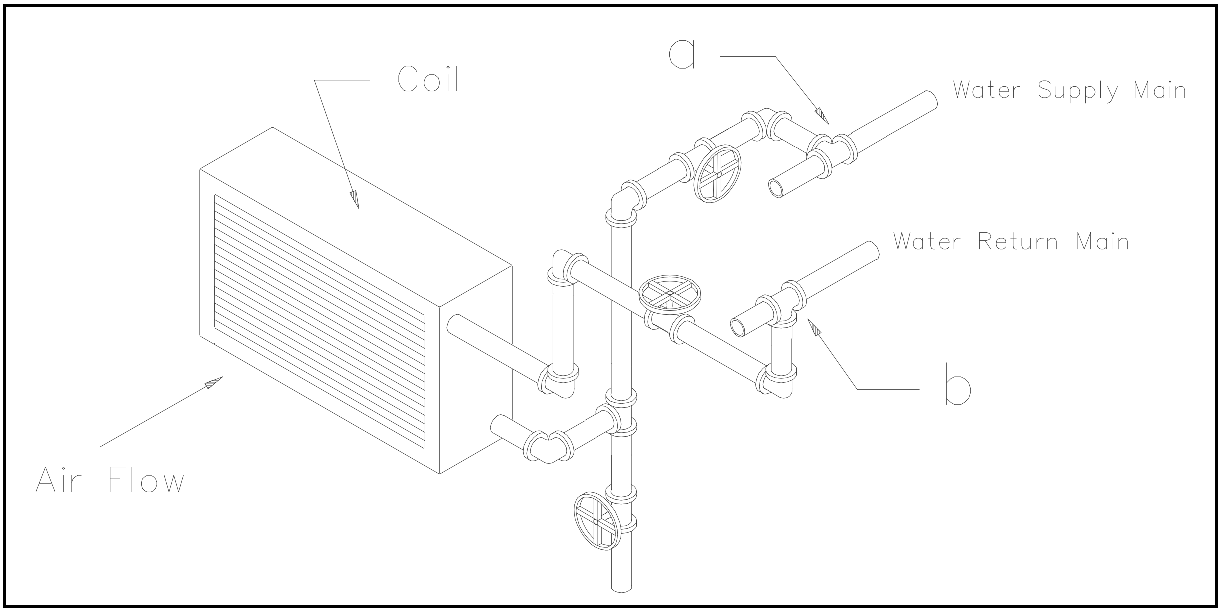


FIGURE 4-3. CONTROL CIRCUIT WITHOUT VALVE.

Note that the specific gravity of the fluid is included in the equation for C_v. It is a dimensionless parameter. Water has a specific gravity that is a function of water temperature, but is very near a value of 1 so that, when using water, this parameter can be dropped. This should be a conscious decision by the designer and not just a habit. For glycol solutions, specific gravity can be determined using tables found in the ASHRAE Fundamentals Handbook chapter on Secondary Coolants (Brines).

The calculated C_v for liquid service is to be shown on the Equipment Schedule for each valve. The Guide Specification requires that, for liquid service, the control valve selected by the contractor have a C_v equal to or no more than 25 percent greater than the value shown on the Equipment Schedule. The control system designer should have ensured that this will meet the application's requirements.

As an example, assume that a control valve is to be selected for a heating coil similar to that shown in Figure 4-3. The maximum heating water temperature is 200° F, the inlet pressure to the valve is 20 psig, the design flow is 50 gpm, and the pressure drop through the circuit, without the control valve, is 4 psig. From Table 4-1, the vapor pressure at 200° F is 11.529 psia and the maximum allowable valve pressure drop from Equation 4-3 is:

$$\Delta P_{max} = 0.45 \times ((20 + 14.7) - 11.529) = 10.43\ psid$$

A water temperature of 200° F is common for heating applications. If the heating water temperature were reduced or the application was for a chilled water coil, the vapor pressure of the fluid would be less and the maximum allowable valve pressure drop would be larger.

TABLE 4-1. VAPOR PRESSURE OF WATER.

Temperature (E F)	Vapor Pressure (psia)	Temperature (E F)	Vapor Pressure (psia)
32.018	0.08866	100	0.9503
40	0.12166	120	1.6945
50	0.17803	140	2.892
60	0.2563	160	4.745
70	0.3632	180	7.515
80	0.5073	200	11.529
90	0.6988	212	14.698

The actual pressure drop through the valve should be less than the maximum allowable but more than through the controlled circuit without the control valve. A design value of 6 psid would appear to be a good selection. Using Equation 4-4, this would result in a specified C_v of:

$$C_v = \frac{GPM}{\sqrt{\Delta P/SG}} = \frac{50}{\sqrt{6/1}} = 20.41$$

If a C_v of 20 is shown on the Equipment Schedule, the contractor can supply a valve with an actual C_v of 21 to 25. At these two extremes, the actual pressure drop across the valve would be 5.66 psid (for $C_v = 21$) and 4.0 psid (for $C_v = 25$). In either case, the pressure drop across the valve is greater than across the circuit without the valve and less than the maximum allowable. The valve will provide good control. On occasion, it may be necessary for the designer to try several different design pressure drops to select the appropriate C_v to ensure good control without cavitation.

Manufacturers provide listings of their valves with C_v values. It should not be difficult to calculate and select an appropriate C_v for most control valve applications.

5. **C_v Calculation For Steam Service**.

a. **General**. The calculation of a steam valve flow coefficient requires a different approach than that for a water valve.

b. **Critical Pressure Drop**. In a properly sized steam valve, the pressure drop across the fully opened valve will be equal to or slightly below the critical pressure drop. The critical pressure drop across a steam valve is defined as the pressure differential across the fully opened valve that results in choked flow at the design flow rate. Under choked conditions, the flow rate through the valve is sonic and does not depend on the pressure differential across the valve but on the area of the valve opening only. The valve's C_v should be calculated so that the design flow condition is obtained at or slightly below critical pressure drop.

The critical pressure drop, ΔP_{cr}, is calculated using the following equation:

$$\Delta P_{cr} = K_m \times P_e \qquad \text{Eq. 4-5}$$

where:

K_m = 0.45
P_e = Absolute steam inlet pressure to valve, psia.

Equation 4-5 works well for a valve inlet pressure greater than 26.7 psia. When the inlet pressure is less than 26.7 psia, the designer should have avoided designing for a pressure drop that results in an outlet pressure equal to or less than atmospheric pressure. This concern is illustrated by the following use of Equation 4-5, assuming an inlet pressure of 26.7 psia:

$$\Delta P = K_m \times P_e$$

$$P_e - P_{out} = K_m \times P_e$$

rearranging:

$$P_{out} = P_e - (K_m \times P_e)$$

$$P_{out} = 26.71 - (.45 \times 26.71\ psia)$$

$$P_{out} = 14.69\ psia = atmospheric\ pressure$$

therefore:

$$P_{out} = 0\ psig$$

An outlet pressure at or below atmospheric pressure is inappropriate unless the system is designed to operate on low or negative pressures. Steam coils and convertors have specific inlet pressure requirements that must be met to ensure proper functioning. This is especially true of steam convertors because the condensate outlet is at atmospheric pressure. An inlet pressure at or below atmospheric pressure will result in no flow. Therefore, when the inlet pressure is at or below 26.7 psia, the designer should have assumed that the pressure drop across the valve is equal to the inlet pressure and should not use Equation 4-5.

c. **Superheated steam.** Saturated steam is used in most HVAC applications. Superheated steam may be present in district heating applications where pressure-reducing valves are used to lower the system pressure of saturated steam near the control valve inlet. This is called a throttling process and the thermodynamics of the process must be considered as they may impact the selection of the appropriate C_v equation used to size the steam control valve.

Throttling results in pressure reduction of the steam on the downstream side of the pressure-reducing valve. If the pressure is reduced far enough, superheating of the steam will occur. The concept of throttling is often used to calculate the quality (percent of moisture) of steam using a device called a throttling calorimeter. The underlying principle in throttling is that the enthalpy of the steam before and after throttling is constant.

On a temperature versus entropy diagram (Figure 4-4), steam is superheated if it is to the right of the dry saturated steam line. Steam along the dry saturated steam line is 100 percent in quality (i.e., no moisture). To the left of the saturated steam line, the steam is less than 100 percent quality.

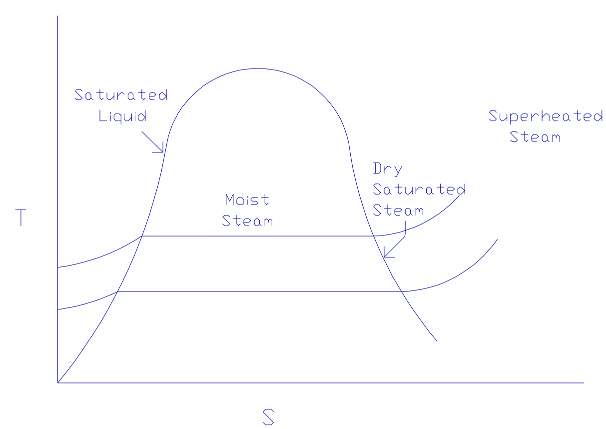


FIGURE 4-4. TEMPERATURE-ENTROPY DIAGRAM FOR STEAM.

The number of degrees of superheat is determined by subtracting the temperature of the superheated steam from the temperature of dry saturated steam at the same enthalpy as the superheated steam. Table 4-2 can be used if the steam at the inlet to the pressure-reducing valve is 100 percent quality (i.e., if it lies on the dry saturated steam line) and the pressures at the inlet (P_i) and outlet (P_o) of the pressure-reducing valve are known. An alternative method of determining the degrees of superheat is to refer to an enthalpy versus entropy (or, Mollier) diagram.

TABLE 4-2. DEGREES OF SUPERHEAT (°F) FOR STEAM PASSING THROUGH A PRESSURE-REDUCING VALVE.

PRV Outlet Pressure (psia)	PRV Inlet Pressure (psia)				
	100	150	200	250	300
35	39	53	61	67	71
30	46	60	68	74	78
25	53	67	76	82	86
20	62	76	86	92	95
14.696	76	90	100	106	108

d. C_v Equations For Steam Service. Based on the above discussion, the C_v calculation for a steam valve depends on two conditions:

1. Whether the pressure drop across the valve will be less than or greater than the critical pressure drop
2. Whether the steam is saturated (i.e., containing moisture, thus having a quality of 100 percent or less) or is superheated.

The four C_v equations used to size valves and the conditions governing their selection are as follows:

1. For saturated steam and a valve pressure drop that is less than the critical pressure drop:

$$C_v = \frac{Lbs\ of\ steam\ per\ hour}{2.11 \times \sqrt{(P_e + P_o) \times \Delta P}} \qquad \text{Eq. 4-6}$$

where:

- 2.11 = Compressibility constant
- P_e = Absolute pressure of entering steam, psia
- P_o = Absolute pressure of exiting steam, psia
- ΔP = Pressure drop across valve, psid

2. For saturated steam and a valve pressure drop that is greater than or equal to the critical pressure drop:

$$C_v = \frac{Lbs\ of\ steam\ per\ hour}{1.74 \times P_e} \qquad \text{Eq. 4-7}$$

where:

1.74 = Compressibility constant
P_e = Absolute pressure of entering steam, psia

3. For superheated steam and a valve pressure drop that is less than the critical pressure drop:

$$C_v = \frac{(Lbs\ of\ steam\ per\ hour) \times [1 + (.0007 \times T_{sh})]}{2.11 \times \sqrt{(P_e + P_o) \times \Delta P}} \qquad \text{Eq. 4-8}$$

where:

T_{sh} = Degrees Fahrenheit of superheat, °F
2.11 = Compressibility constant
P_e = Absolute pressure of entering steam, psia
P_o = Absolute pressure of exiting steam, psia
ΔP = Pressure drop across valve, psid

4. For superheated steam and a valve pressure drop that is greater than or equal to the critical pressure drop:

$$C_v = \frac{(Lbs\ of\ steam\ per\ hour) \times [1 + (.0007 \times T_{sh})]}{1.74 \times P_e} \qquad \text{Eq. 4-9}$$

where:

T_{sh} = Degrees of superheat, ° F
P_e = Valve inlet pressure, psia

e. **Valve Selection**. Steam valves are to be of the equal-percentage type. If the calculated C_v is greater than 55, the designer should have specified two valves operating in parallel such that the C_v of one valve is one-third and the other valve is two-thirds of the total C_v. The valve actuators should be sequenced so that the smaller valve opens first over the first one-third of the controller's output range followed by the larger valve, which opens over the last two-thirds of the output range. For example, the smaller valve's positive positioner should be set to operate between 3 and 7 psig and the larger valve's positive positioner should be set to operate between 7 and 15 psig. This helps to ensure close temperature control.

6. **C_v Calculation for Butterfly Valves**. The procedure for selecting and sizing butterfly valves is similar to that for other types of valves except for one difference. The maximum controllable flow through a butterfly control valve usually occurs when the discs are approximately 70 percent open. Therefore, the butterfly valve's C_v is calculated at the valve's 70 percent open position. Between the 70 and 100 percent open positions, butterfly valves do not have good modulating characteristics due to flow interference around the discs. Designers are advised that for some manufacturers' butterfly valves, the maximum controllable flow may be at a valve position other than the 70 percent open position. In general, however, 70 percent is a good value to specify.

The flow characteristic of typical butterfly valves can be compared to the characteristic of a typical equal-percentage globe valve by reviewing Figure 4-5.

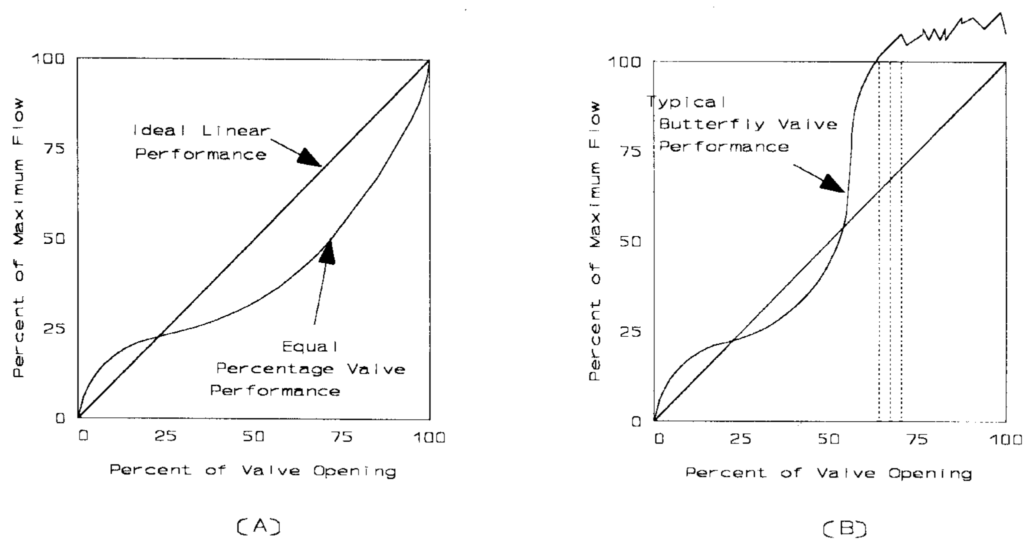


FIGURE 4-5. FLOW CHARACTERISTICS OF: (A) EQUAL-PERCENTAGE GLOBE TYPE VALVE, (B) TYPICAL BUTTERFLY VALVE.

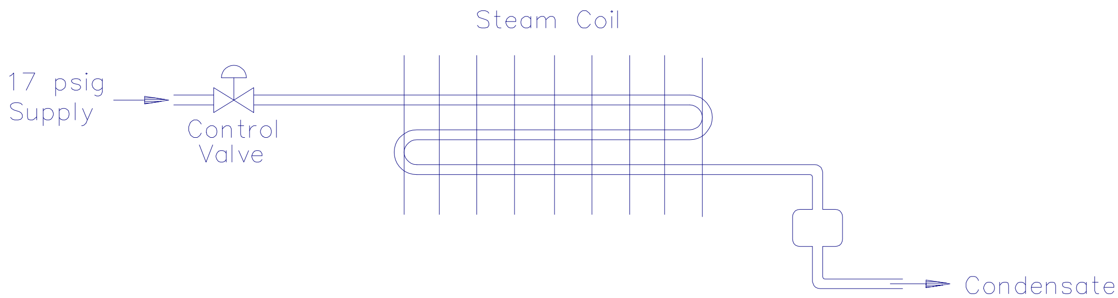
Butterfly valves are typically used in large flow applications because they are very economical and have good large volume flow characteristics. One drawback is that butterfly valves do not usually have very good leakage ratings. The HVAC Control Guide Specification requires valves that are 4 inches or larger to be of the butterfly type.

The procedure for calculating C_vs for butterfly valves is basically identical to that for other water and steam service control valves. The only difference, as discussed above, is that the C_v (defined as the ratio of design flow to maximum flow) is to occur at the valve's 70 percent open position. The calculated C_v should be shown on the Equipment Schedule.

7. **Example Problems.** The following examples supplement those shown in the Technical Manual.

Example 1

A steam coil rated at 1000 pounds per hour (lb/hr) at an inlet pressure (P_i) of 2 psig is to be supplied with saturated steam from a boiler at a system pressure of 17 psig at the valve inlet (P_e). Calculate the control valve's C_v.



1. Determine the valve inlet absolute pressure, P_e.

$$P_e = 17 \text{ psig} + 14.7 \text{ psia} = 31.7 \text{ psia}$$

2. Using Equation 4-5, calculate the critical pressure drop.

$$\Delta P_{cr} = K_m \times P_e = 0.45 \times 31.7 \text{ psia}$$
$$\Delta P_{cr} = 14.265 \text{ psid}$$

3. Calculate the valve pressure drop.

$$\Delta P = P_e - P_i$$
$$\Delta P = (17 \text{ psig} + 14.7 \text{ psia}) - (2 \text{ psig} + 14.7 \text{ psia})$$
$$\Delta P = 15 \text{ psid}$$

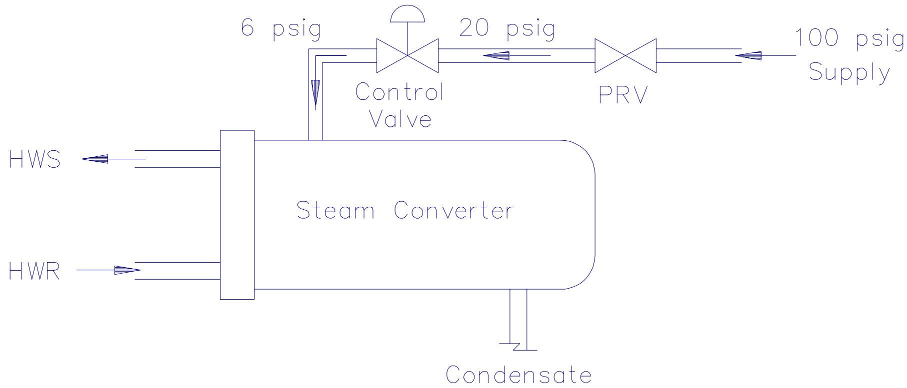
4. The steam is saturated and the valve pressure drop is greater than the critical pressure drop. Using Equation 4-7:

$$C_v = \frac{1000 \ lb/hr}{1.74 \times 31.7 \ psia} = 18.3$$

Therefore, the C_v range should be from 19 to 22.

Example 2

A steam convertor rated at 1000 lb/hr requiring an inlet pressure of 6 psig is to be supplied with saturated steam. A steam dispatching system supplies saturated steam at a pressure of 100 psig. The steam pressure is reduced to 20 psig near the valve through a pressure-reducing valve. Calculate the number of degrees of superheat and the control valve's C_v.



1. Determine the valve absolute inlet pressure (P_e).

$$P_e = 20 \text{ psig} + 14.7 \text{ psia} = 34.7 \text{ psia}$$

2. Using Equation 4-5, calculate the critical pressure drop.

$$\Delta P_{cr} = 0.45 \text{ x } 34.7 \text{ psia}$$
$$\Delta P_{cr} = 15.615 \text{ psid}$$

3. Calculate the valve pressure drop.

$$\Delta P = (20 \text{ psig} + 14.7 \text{ psig}) - (6 \text{ psig} + 14.7 \text{ psig})$$
$$\Delta P = 14 \text{ psid}$$

4. Since there is pressure reduction there will be superheating of the steam. The amount of superheating (T_{sh}) can be determined using Table 4-2.

   PRV_i = 100 psig = 114.7 psia (PRV inlet pressure)
   PRV_o = 20 psig = 34.7 psia (PRV outlet pressure)

   a. Interpolate for T_{sh} between 39° F and 46° F at an upstream pressure of 100 psia: T_{sh} = 39.4° F

   b. Interpolate for T_{sh} between 53° F and 60° F at an upstream pressure of 150 psia: T_{sh} = 53.4° F

   c. Interpolate between 39.4° F and 53.4° F (the above results) at 114.7 psia: T_{sh} = 43.5° F

5. For superheated steam where the valve pressure drop is less than the critical pressure drop:

$$C_v = \frac{(1000\ lb/hr) \times [1 + (.0007 \times 43.5^o\ F)]}{2.11 \times \sqrt{(34.7 + 20.7) \times (34.7 - 20.7)}} = 17.53$$

Therefore, a C_v range between 18 and 21.9 should be selected.

C. DRY BULB ECONOMIZER DEVIATION CONTACT CALCULATIONS

1. **General.** An economizer cycle is designed to allow the use of outdoor air to satisfy a part or all of a system's cooling load. This is possible during the spring and fall, at night and during the early morning, on cool summer days and at high altitudes. Ideally, an economizer cycle would compare the total heat content (enthalpy) of the outdoor air and the return air. In the cooling cycle, the economizer cycle would operate whenever the enthalpy of the outdoor air was less than that of the return air. This would result in maximum energy savings.

   In practice, however, accurate and reliable measurement of enthalpy is very difficult. The necessary sensors are very expensive and require almost constant attention to ensure proper system calibration and operation. As an alternative, economizer cycle operation based on comparison of the return air and outside air dry bulb temperatures provides most of the energy savings possible with enthalpy control but without the major disadvantages. The hardware required is relatively inexpensive, is accurate and reliable, and requires minimal attention to maintain system calibration and proper operation.

2. **Dry Bulb Economizer Function.** The dry bulb economizer controller essentially operates as a switch to allow the mixed air temperature controller to modulate the system dampers when each of two conditions are satisfied:

   a. **Switching Condition 1.** This switching condition is based on a measurement of the return air dry bulb temperature. Typically, the return air temperature is nearly the same as the space temperature. Space temperature is usually controlled from a space thermostat that has a setpoint that is changed from season to season. The setpoint range is typically 68 to 78° F or possibly 70 to 76° F. If, for example, a given system requires cooling whenever the return air exceeds 73° F, an economizer cycle would not operate whenever the return air temperature is below 73° F. When the return air exceeds this temperature, however, the space has a cooling load and the economizer can operate if the second condition is also satisfied.

      The return air temperature is the process variable input to the economizer controller. Information included by the designer on the Equipment Schedule is the temperature at which the process variable (PV) contact is closed and the temperature at which the PV contact is open. The midpoint between the open and closed temperatures is the PV contact's setpoint. The magnitude of the switching differential establishes the open and closed temperatures. For example, the contact is closed when the return air temperature is 73° F and open when the temperature is 71° F. Thus the switching differential is 2E F. This switching differential prevents rapid cycling of the dampers with small changes in outside air temperature.

Note that this control system is based on a significant difference between the heating season and the cooling season thermostat setpoints and that the switchover temperature must be within this range. If the space thermostat setpoint is reset by the user to a value not consistent with the assumed range, the economizer controller PV contact setpoint may also need to be changed. If the user eliminates the deadband by using the same or essentially the same setting for heating and cooling, the economizer cycle may not function as designed. It should be noted that the use of a deadband is required for all Federal facilities by 11 CFR 435.

b. **Switching Condition 2.** The second condition that must be satisfied for economizer operation is based on a comparison between the return air and the outside air dry bulb temperatures. As discussed previously, it is desirable to permit modulation of the dampers to admit outdoor air for cooling when the enthalpy of the outdoor air is less than that of the return air. Local weather data can be used to determine the difference between these two temperatures that, on the average, results in the enthalpy of the outdoor air being less than that of the return air. This difference between the outdoor and return air temperatures is the Deviation (DEV) contact setpoint of the economizer controller.

Information provided on the Equipment Schedule for Condition 2 is the temperature difference at which the DEV contact is closed and the temperature at which it is open. The midpoint between open and closed is the DEV contact's setpoint. The magnitude of the switching differential establishes the open and closed temperatures. With the contact closed when the difference between the outdoor and return air is 8E F and open when the difference is 6E F, the switching differential is 2E F.

3. **Calculation of the DEV Contact Setpoint.** As discussed above for Condition 2, the contact setpoint for the deviation between the outdoor and return air dry bulb temperatures must be calculated. Figure 4-6 is a psychrometric chart illustrating the selection of this setpoint. A cooling design condition (point A) of 78E F and 50 percent relative humidity has been selected and a constant enthalpy line (B-C) drawn. If the outside air conditions are below this line, the total heat content of the outside air is less than that of the return air and the outside air can be selected for cooling. A conservative approach would be to base the switchover to economizer operation on points D and E or 13E F. This should ensure that the economizer cycle will not operate when the outside air heat content is above the heat content of the return air.

To maximize the effective use of the economizer cycle, a switchover differential based on local climatic conditions should be used. A line representative of the average outside conditions can be constructed from the bin weather data in AEngineering Weather Data,@ TM 5-785. Line F-G in Figure 4-6 is a plot of the average conditions for Greenville, SC. Each point is the midpoint of the temperature bin and the mean coincident wet bulb temperature. The optimum switchover temperature differential is based on the difference between points E and H or 7E F. In a more humid climate the switchover differential would be larger and in a drier climate the switchover differential would be lower. In extremely dry climates, the average outside conditions line may cross constant enthalpy line B-C to the right of the design point. This indicates that the design relative humidity will seldom be achieved without humidification or evaporative cooling. The switchover temperature differential should be set at 2 to 3E F to prevent cycling of the controls.

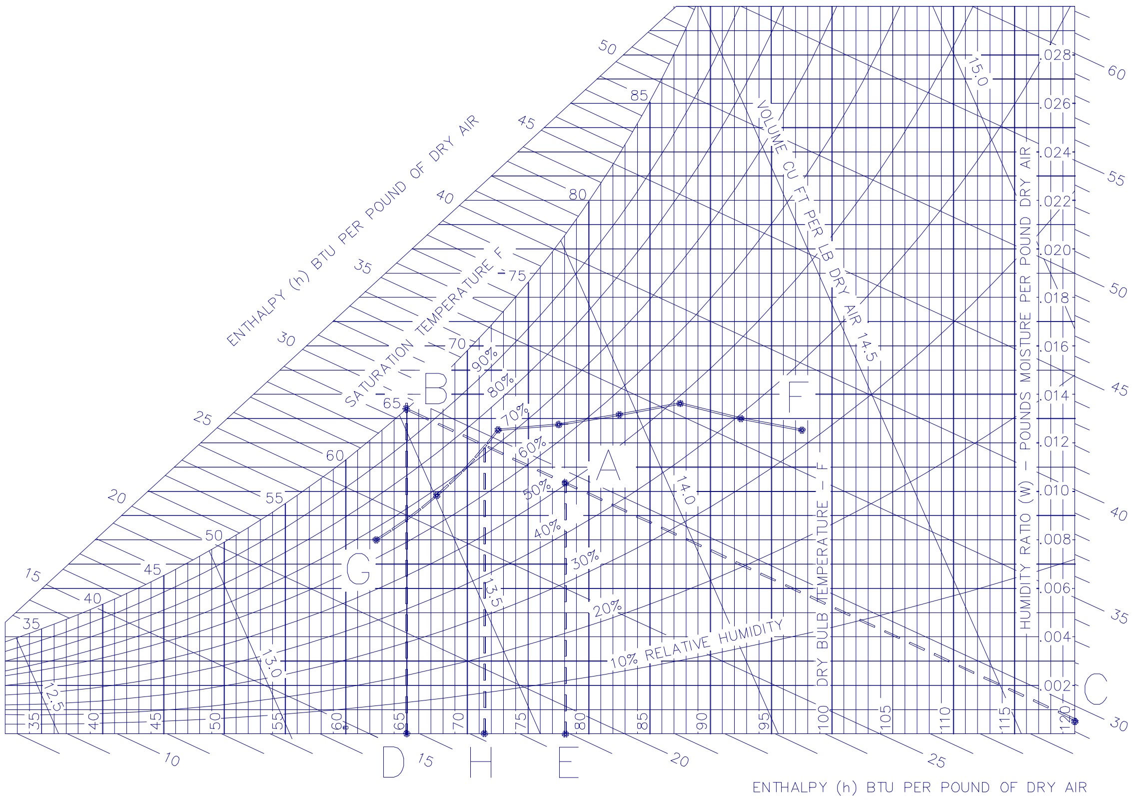


FIGURE 4-6. USE OF PSYCHROMETRIC CHART FOR DETERMINING ECONOMIZER DEVIATION (DEV) CONTACT SETPOINT.

For the economizer controller in this example, the setpoint of the PV contact would be 73E F. It would be set to close at 74E F and open at 72E F, thus having a switching differential of 2E F. The setpoint of the DEV contact would be 7E F. It would be set to close at 8E F and open at 6E F with a switching differential of 2E F.

The following is a summary of the steps involved in determining the deviation contact setpoint:

1. Plot a constant enthalpy line through the design return air temperature and relative humidity (B-C).

2. Plot the average weather line (G-F). Use the midpoint of each OA dry bulb bin and its corresponding mean coincident OA wet bulb (saturation temperature) from TM-5-785.

3. Draw a vertical line down from the intersection of lines B-C and G-F.

4. The deviation contact setpoint is the difference between points H and E.

D. RESET CONTROL CALCULATIONS

1. **General.** The setpoint of a heating coil controller is often changed or Areset@ in response to the outdoor air temperature. Such a control scheme is shown in Figure 4-7. The reset controller's 4-20 mA output is the control point adjustment (CPA) input to the temperature controller and results in the temperature setpoint of the heating coil (H/C) being reset in response to the outdoor temperature.

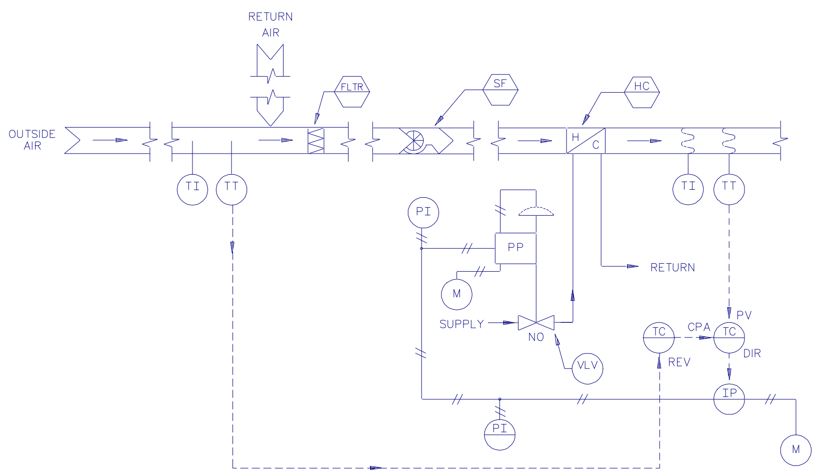


FIGURE 4-7. HEATING COIL WITH SETPOINT RESET.

A similar and common application of reset control is in hydronic applications as shown in Figure 4-8. Here the heating water temperature for a facility is reset based on outdoor air temperature. Again, the output of the reset controller is the CPA input to the temperature controller. The relationship between the reset controller's process variable input (in this example, the outside air temperature) and the temperature controller's setpoint (building heating water temperature) is called the Reset Schedule. There are four controller configuration parameters that are provided by the designer on the Equipment Schedule to establish the Reset Schedule. These are the setpoint, the proportional band, the maximum controller output signal, and the manual reset (MR) setting.

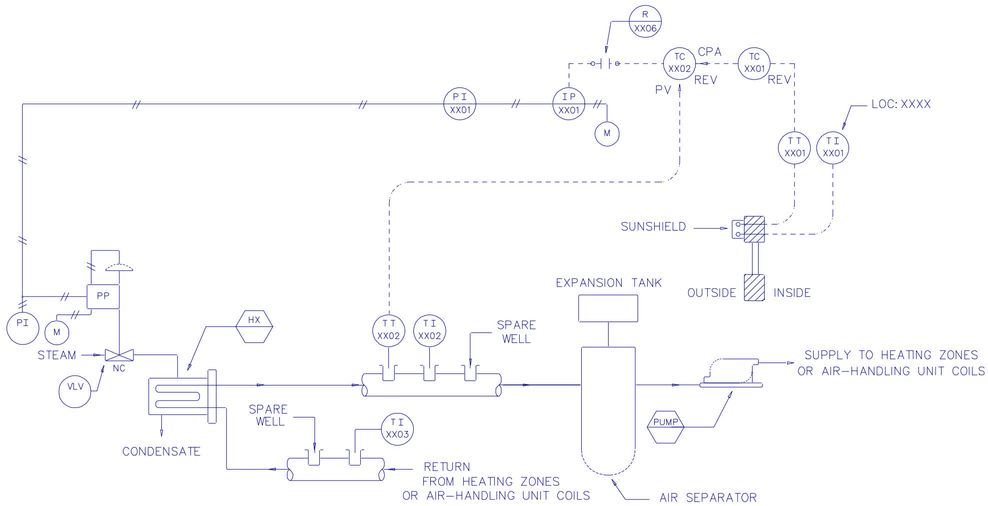


FIGURE 4-8. HYDRONIC APPLICATION WITH SETPOINT RESET.

Before discussing configuration parameters, several terms must be defined. The Reset Schedule is a linear relationship between a PV and the setpoint. A detailed example for a hot water application is shown in Figure 4-9. The PV (outside air temperature) is represented on the horizontal axis while the reset controller's output (heating water setpoint) is shown on the vertical axis.

On the vertical axis, the upper end of the reset schedule line corresponds to a 20 mA output from the reset controller and the lower end of the line corresponds to a 4 mA output. This corresponds to the span of the hot water temperature controller. For a 20 mA input, the hot water temperature controller's setpoint will be 250E F and at 4 mA its setpoint will be 100E F. This range or span is dictated by CEGS 15950.

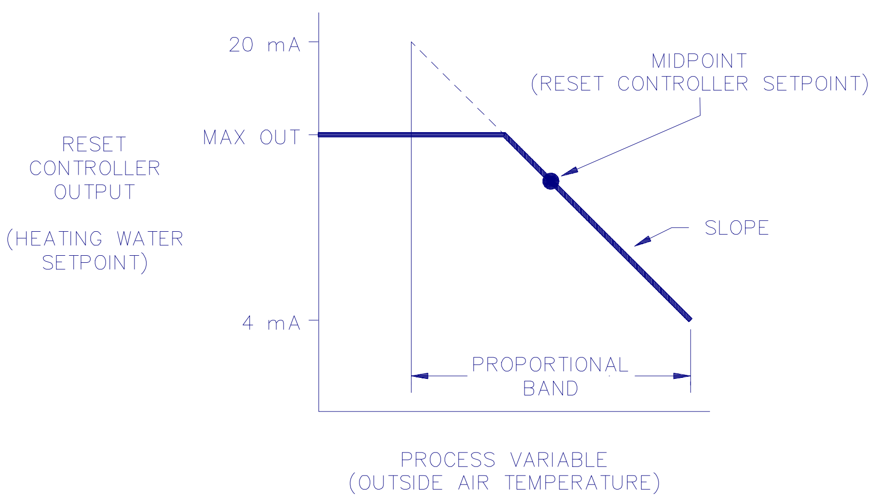


FIGURE 4-9. SETPOINT RESET CONTROLLER FUNCTION.

The reset controller is configured to limit its output to a maximum value (Max Out). This establishes the highest output that it will send to the hot water controller. There is an inverse relationship between the reset controller's output and the PV input. An increasing PV results in a decrease in the controller output. To achieve this relationship, the reset controller must be reverse-acting (REV).

By definition, the reset controller's setpoint is at the midpoint of the proportional band. This assumes that the value of the MR is 50 percent. Changes in the value of the reset controller's setpoint will shift the Reset Schedule line to the right or left.

The proportional band is the difference in the values of the process variable over the range of the reset controller's output. This is illustrated in Figure 4-10 as $(OA_2 - OA_1) / (HW_1 - HW_2)$ and is further explained in the following example. The proportional band can also be defined as the inverse of the slope. Changing the proportional band changes the slope and length of the line as it rotates about the midpoint (the reset controller's setpoint).

2. **Configuration Parameter Calculation.** As an example of the calculations necessary for determining the reset controller's configuration parameters, consider a typical design that is based on a 200° F heating water temperature at an outside design temperature of 0° F. This is design point "a" in Figure 4-10. Calculations indicate that at an outside temperature of +30° F, a heating water temperature of 165° F can easily satisfy the load. This is design point "b." In addition, the design should ensure that the heating water temperature never exceeds 200° F regardless of the outdoor temperature. The solid line shown in the Reset Schedule of Figure 4-10 represents these conditions. Based on this information the configuration parameters for the reset controller can be calculated.

An important consideration in the following calculations is that the Guide Specification requires the heating water temperature transmitter to have a span of 100 to 250° F. The CPA input to the hot water temperature controller from the reset controller must be scaled to this same range. Therefore when the reset controller's output is 20 mA, the setpoint of the hot water temperature controller will be 250° F and, when the output is 4 mA, the setpoint will be 100° F. This span then defines the values of HW_1 and HW_2 in Figure 4-10.

Given that the values of HW_1 and HW_2 are known (HW_1 = 250° F and HW_2 = 100° F), their corresponding points on the Reset Schedule line, OA_1 and OA_2, can be found if the slope of the line is known. The slope of the line can be found from the two design points.

$$Slope = \frac{HW_a - HW_b}{OA_a - OA_b} = \frac{200 - 165}{0 - 30} = -1.17 \qquad \text{Eq. 4-10}$$

OA_1, corresponding to HW_1, can be calculated by again using the slope equation, the calculated slope, and one of the design points on the reset schedule line.

$$Slope = \frac{HW_1 - HW_a}{OA_1 - OA_a} \qquad \text{Eq. 4-11}$$

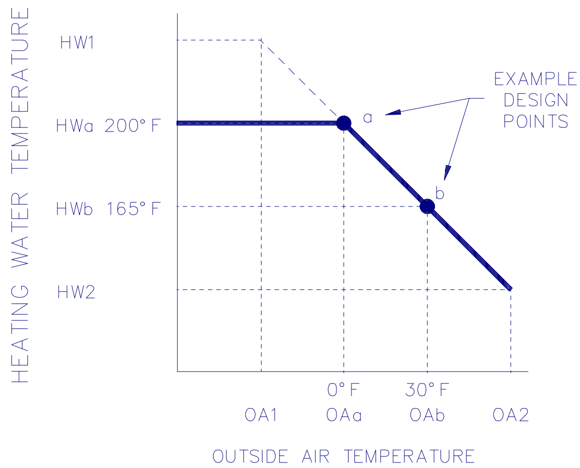


FIGURE 4-10. EXAMPLE RESET SCHEDULE.

Rearranging Equation 4-11 gives:

$$OA_1 = \frac{HW_1 - HW_a}{Slope} + OA_a = \frac{250-200}{-1.17} + 0 = -42.7^o\ F$$

Similarly, OA_2 can be calculated.

$$OA_2 = \frac{HW_2 - HW_a}{Slope} + OA_a = \frac{100-200}{-1.17} + 0 = 85.5^o\ F$$

The proportional band setting (in percent) for the reset controller is the throttling range of the process variable (OA_2 minus OA_1 in this example) divided by the span of the setpoint adjustment:

$$PB = \frac{(OA_2 - OA_1)\times 100}{HWSpan} = \frac{(85.47-42.74)\times 100}{250-100} = 85.5\ \% \qquad \text{Eq. 4-12}$$

The reset controller's setpoint (SP) is the midpoint of the throttling range:

$$SP = \frac{OA_2 - OA_1}{2} + OA_1 = \frac{85.47-42.74}{2} - 42.74 = 21.4^o\ F \qquad \text{Eq. 4-13}$$

The procedure described above for calculating the setpoint assumes that the value of the MR is 50 percent.

The reset controller must also limit the setpoint of the temperature controller to 200°F (Max SP). This can be accomplished by limiting the output of the reset controller. This controller feature is often referred to as "Max Output" or "Output High" and is specified as a percentage of the signal output where 0 percent corresponds to 4 mA and 100 percent corresponds to 20 mA. The hot water controller recognizes a 4 mA CPA input as 100°F (Lo Span) and a 20 mA CPA input as 250°F (Hi Span). As discussed previously, this is the span of the hot water temperature controller (HW Span). Equation 4-14 calculates the reset controller's maximum output (Max Out).

$$Max\ Out = \frac{(Max\ SP - Lo\ Span) \times 100}{HW\ Span} = \frac{(200-100) \times 100}{250-100} = 67\% \qquad \text{Eq. 4-14}$$

If the output of the reset controller is limited to 67 percent of its maximum output (14.7 mA), the heating water setpoint will never exceed 200°F.

E. SUPPLY/RETURN FAN VOLUME CONTROL CALCULATIONS

1. **General.** Many VAV systems can effectively operate without a return air fan if the system is properly designed. The use of short and/or large return air ducts is recommended to avoid the need for a return air fan on VAV systems. If the pressure drop through the return air ductwork exceeds 0.5 inches of water, a return air fan should be provided.

   The controlled space should be maintained at a positive pressure to prevent unwanted infiltration. A minimum amount of outside air must also be supplied to the space to ensure a healthy indoor environment. The system must maintain a constant air flow differential between the supply air and return air even as the total air quantity circulated in the building is varied in response to the cooling load. If it is determined that a return fan is necessary, it must be sequenced with the supply fan to provide a constant air flow differential. This is an inherently difficult control process.

2. **Controller Functions.** The control loop required to sequence the operation of two fans in a VAV application is shown in Figure 4-11. The fan controller accepts a signal from the return duct air flow measuring station as its process variable input. A signal from the supply duct flow measuring station is sent to the CPA port and resets the setpoint of the fan controller based on the supply air volume. The fan controller compares the return air flow signal with its setpoint and adjusts the return air fan inlet vanes accordingly.

   The signal from the supply air flow measuring station is a direct input to the CPA port of the return fan controller. The first function performed by the controller is to scale the signal to the same cfm range as the process variable input. To establish the appropriate setpoint signal, this scaled signal must be ratioed and biased. The ratio action compensates for differences in the supply and return duct cross-sectional areas and any differences in the spans of the supply and return air flow transmitters. The bias function subtracts a cfm quantity from the ratioed signal to establish the constant flow differential requirement.

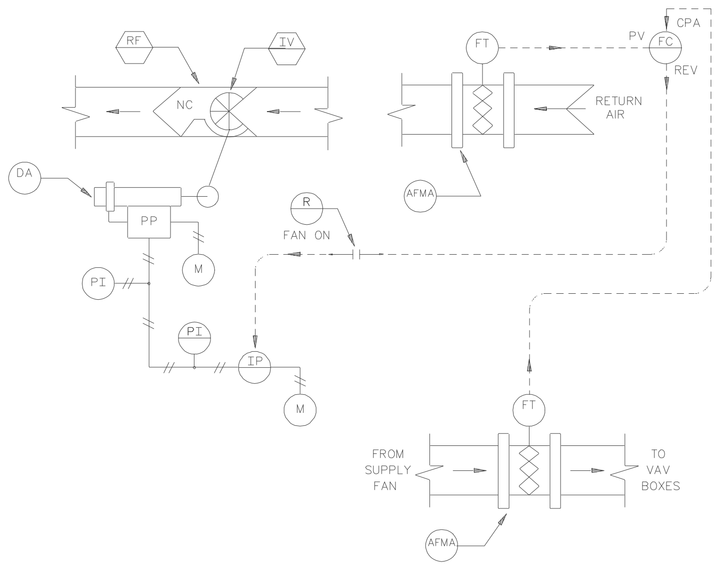


FIGURE 4-11. RETURN FAN VOLUME CONTROL LOOP.

3. **Sample Calculations.** As an example, consider a VAV system with a maximum supply air flow of 10,000 cfm and a desired flow differential between the supply and return air flows of 2,500 cfm. The supply and return air ducts have cross-sectional areas of 10 ft^2 and 20 ft^2, respectively. Flow transmitters with the appropriate fpm spans must first be selected for both the return and supply air flow measuring stations. These stations measure flow velocity and not volume (cfm). The supply air transmitter range can be selected to be 4 mA at 0 fpm and 20 mA at 1,200 fpm. These values represent a supply air volume of 0 cfm and 12,000 cfm, respectively. A flow transmitter can be selected for the return air side that has the same range. Note that a 20 mA signal corresponds to a velocity of 1,200 fpm but the volume is 24,000 cfm since the area of the return air duct is 20 ft^2.

Based on the above information, the ratio setting to be input into the controller can be calculated. The ratio is a dimensionless parameter defined by the mathematical expression:

$$Ratio = \frac{Area_s}{Area_r} \times \frac{FPM_s}{FPM_r} \qquad \text{Eq. 4-15}$$

where:

$Area_s$ = Cross-sectional area of the supply duct
$Area_r$ = Cross-sectional area of the return duct
FPM_s = Supply air flow transmitter span
FPM_r = Return air flow transmitter span

In the above example, this value is:

$$Ratio \; ' \; \left(\frac{10}{20}\right) \times \left(\frac{1200}{1200}\right) \; ' \; 0.5$$

The desired bias can be entered directly into the controller. In the example, the bias configuration parameter is -2,500 cfm.

The example's configuration parameters are shown in Table 4-3. The effects of scaling, ratioing, and biasing are illustrated in response to various supply duct transmitter flow signals. Note that the biased CPA, which is the resulting setpoint of the controller, is a constant 2,500 cfm less than the Supply Actual Flow (cfm).

TABLE 4-3. RETURN FAN CONTROLLER RATIO AND BIAS EXAMPLE.

SUPPLY DUCT		RETURN FAN CONTROLLER			
Sensed Flow (fpm)	Actual Flow (cfm)	RSP Input (mA)	Scaled CPA (cfm)	Ratioed CPA (cfm)	Biased CPA (cfm)
0	0	0.0	0	0	0
240	2400	7.2	4800	2400	0
500	5000	10.7	10000	5000	2500
600	6000	12.0	12000	6000	3500
840	8400	15.2	16800	8400	5900
1000	10000	17.3	20000	10000	7500
1200	12000	20.0	24000	12000	9500

F. AIR DAMPER SIZING CALCULATIONS

1. **General.** Control dampers, like valves, are used to restrict flow. The difference is that with dampers the control medium is air. In a single duct they perform similar to a two-way valve. In a mixed air handling section, the return air damper and outdoor air damper assemblies act as a three-way mixing valve used to control flow quantities of the outside air and return air, thus the temperature of the mixed air. Although each of the mixed air dampers is in a separate ductwork section, they must work together as a system. The outdoor air and return air dampers can be viewed as a subsystem within this system and the relief/exhaust air and return air dampers can be viewed as another subsystem. The outside air and return air damper subsystem

functions similarly to a mixing valve, mixing the air flows to regulate the mixed air temperature. Similarly the exhaust air and return air dampers resemble a diverting valve. Both subsystems must have linear characteristics.

2. **Damper Selection.** Most dampers used in the standard control systems are an integral part of a packaged unit such as VAV boxes, face-and-bypass units, and multizone units. Mixed air dampers consisting of an outside air, return air, and relief air damper are usually not part of a packaged unit. The sizing and selection of mixed air dampers as required in the standard systems entails the use of duct-size parallel blade dampers oriented such that the outside and return air damper air streams are directed into each other to provide for maximum mixing of the flows.

3. **Mixed Air Damper Characteristics.** The following discussion is provided to give insight into the operational characteristics of mixed air dampers. In a mixed air temperature control application, it is desirable to obtain a linear relationship between the movements of the outdoor and return air dampers and the resulting mixed air temperature. An ideal relationship is illustrated in Table 4-4, assuming an outside air temperature of 50E F and a return air temperature of 70E F. This relationship would be fairly simple to obtain if each damper had a linear installed characteristic.

TABLE 4-4. RELATIONSHIP BETWEEN DAMPER MOVEMENT AND MIXED AIR TEMPERATURE.

OA Damper (% open)	RA Damper (% open)	MA Temperature (E F)
100	0	50
75	25	55
50	50	60
25	75	65
0	100	70

There are two basic damper designs, parallel and opposed blades. In a parallel blade damper assembly, each damper blade modulates in the same direction. In an opposed blade damper assembly, each damper blade modulates in a direction opposite to that of its adjacent blades. Ideally, as a damper's blades are modulated, there will be a linear relationship between the stroke of the actuator and the resulting air flow, but with parallel and opposed blade dampers this is not the case.

The inherent characteristic of a damper assembly is defined as the flow versus percent of damper actuator stroke at a constant pressure drop across the damper. The inherent characteristic of both a parallel blade damper and an opposed blade damper is equal percentage. As the damper begins to modulate open, the rate of change of air flow through the damper increases slowly at first. Then as the damper nears the fully opened position the rate of change of air flow increases more rapidly.

In the mixed air section each of the mixed air dampers modulates at the same time. This results in an interaction between the dampers such that the characteristic of the individual dampers is altered. An analysis performed by Huntsville Division on both parallel and opposed blade mixed air dampers show that the interaction yields a nearly linear installed characteristic relationship between damper position and the resulting supply air flow. Contributing to the shape of the curve is the outside air damper's interaction with the return air damper as it modulates. In the analysis, the return air damper fitting loss coefficients are identical to those of the outside air damper. Similar analysis for fitting loss coefficients that are radically different for each damper has been shown to not significantly alter the shape of the curve. This indicates that either a parallel or opposed blade damper could feasibly be used in a mixed air application because both will provide a nearly linear installed combined characteristic. The parallel blade damper, however, offers the added advantage of better mixing of the outside and return air streams if the dampers are oriented such that the air streams are directed toward each other. Additionally, the Corps experience with parallel blade mixed air damper assemblies indicates that there have been no significant problems with using parallel blade assemblies.

G. CONTROL LOOP IMPEDANCE

1. **General.** Impedance can be defined as the opposition to electric current in a circuit element (i.e., device, controller, module, etc.). Impedance may also be referred to as resistance. The load impedances of control loop input and output devices, controllers, and function modules may need to be considered in the design of control loops. In the standard systems the control loops have been designed such that input and output load impedances should not pose a problem. In the event that the designer decides a modification of a standard control loop is necessary, load impedance needs to be considered. This subsection addresses input and output loop load impedance considerations.

2. **Control Loop Circuit.** A control loop circuit consists of the various interconnected control devices. A typical control loop circuit wiring diagram is shown in Figure 4-12. In the controller's input loop, the temperature transmitter is powered by a DC power supply. The temperature transmitter provides a signal within the range of 4-20 mA to the single-loop digital controller process variable input. In the output loop, the controller sends a 4-20 mA signal to the current-to-pneumatic (I/P) transducer, which in turn sends a pressure signal to an actuator.

3. **Standard Input And Output Loops.** Most single-loop digital controllers act on a DC input voltage signal. In practice, this is often accomplished by passing the transmitter's 4-20 mA output current through a resistor internal to the controller or connected across the controller's input terminals. The value of this resistance is considered the input resistance (R) of the controller.

   For the standard control loops shown in the Technical Manual, matching the input resistance of the controller with the output power of the transmitter should not be a significant concern. The reason for this is that almost all commercially available transmitters provide sufficient output power to drive at least one controller or device and there are no standard applications where a transmitter is used to drive more than one controller or device.

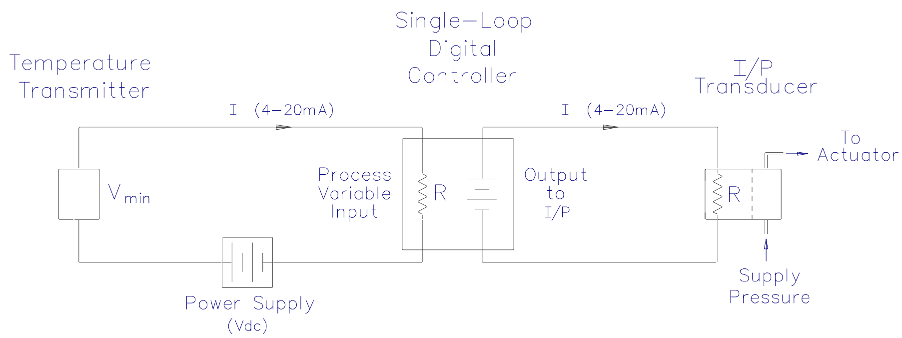


FIGURE 4-12. TYPICAL CONTROL LOOP RESISTANCES.

Most single-loop digital controllers power the output loop. The Guide Specification requires this for standard controllers. This means that the 4-20 mA signal is generated from a power supply within the controller as illustrated in Figure 4-12. The output resistance through which the controller must supply its 4-20 mA signal is represented by the R of the I/P transducer. Single-loop digital controllers have output load resistance ratings indicating the maximum output loop resistance through which they can supply a full 20 mA. In selecting the type and quantity of devices to be placed in the controller output loop, caution must be exercised to avoid exceeding the controller's output load resistance rating. The Guide Specification requires that single-loop controllers be capable of driving a minimum of 600 ohms. This is sufficient to drive two devices and in no case should the designer ever exceed this limit.

4. **Loop-Powered Devices.**

a. **General.** Several of the standard control loop devices are loop-powered. A loop-powered device receives its power to operate from a power supply or sourcing device in series with the loop-powered device. A loop-powered transmitter receiving its power from a series power supply can be seen on the input loop side of Figure 4-12. A loop-powered I/P receiving its power from a sourcing controller can be seen on the output loop side of Figure 4-12.

An identifying characteristic of a loop-powered device is that it has only two wiring connections. This is in contrast to a non-loop-powered device which has at least four wires, two of which are connected to a power source such as 120 VAC. In general, transmitters and I/P transducers are loop-powered devices.

b. **Transmitter Operation.** There are a variety of transmitters used in the standard systems. These include temperature, relative humidity, airflow, and differential pressure transmitter. Most of these are loop-powered. A loop-powered transmitter requires a minimum voltage to be available to it in order for it to operate. This minimum voltage is sometimes called the liftoff voltage and typically is 12 VDC. This is illustrated in Figure 4-13 where V_{min} is the liftoff voltage for a typical transmitter.

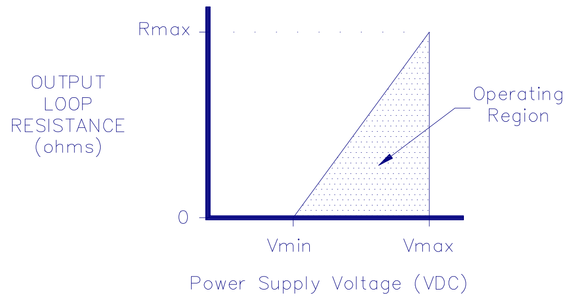


FIGURE 4-13. TRANSMITTER RANGE OF OPERATION.

Figure 4-13 is similar to one that is usually provided by the transmitter manufacturer. The DC power supply voltage is on the horizontal axis and the corresponding transmitter maximum output loop resistance is on the vertical axis. The graph illustrates how the maximum output resistance is constrained by the size of the external DC voltage power supply used to power the transmitter. The larger the power supply the greater the resistance through which the transmitter can provide a full 20 mA signal. Referring to Figure 4-13, if the voltage of the power supply connected to the loop-powered transmitter is equal to V_{min}, the resistance connected to the transmitter output loop through which the transmitter can provide a full 20 mA is 0 ohms. In this case, the transmitter will not work. If the power supply voltage is equal to V_{max}, the transmitter can provide a full 20 mA to a resistance of R_{max}. R_{max} might be as high as 2,000 ohms for a particular transmitter. Figure 4-13 is a graphical illustration of Ohm's law:

$$\text{Current (I)} = \text{Voltage (V)} / \text{Resistance (R)}$$

Applying this to the loop power transmitter:

$$I = (V_{PS} - V_{min}) / R$$

where:

V_{PS} = Power Supply Voltage, VDC
V_{min} = Transmitter liftoff voltage, VDC

This equation is practically applied by rearranging it and substituting some known constraints. One known constraint is the power supply voltage, V_{PS}, which is 24 VDC per the Guide Specification requirement. The other known constraint is the maximum current, 20 mA, that will flow through the circuit. Using this information and assuming that the liftoff voltage, V_{min}, is 12 VDC, one can determine the maximum resistance (R_{max}) of the device(s) connected to the output loop of the transmitter:

$$R_{max} = (V_{PS} - V_{min}) / I$$
$$R_{max} = (24 - 12) / .020 = 600 \text{ ohms}$$

5. **Non-Loop-Powered Devices.** In contrast to a loop-powered device, a non-loop-powered device is externally powered. Several function modules are not loop-powered. These include the minimum position switch, signal invertor, high signal selector, sequencer module, and loop drivers.

6. **Function Modules.**

a. **General.** As mentioned previously, most function modules are not loop-powered. The only exceptions are I/P transducers. Non-loop-powered devices are externally powered from a separate power source such as 120 VAC. The reason for the external power requirement is that they perform tasks that are fairly complex and thus have a large power draw due to the extensive circuitry contained within them. Because function modules are externally powered, they also power their output loop. Function modules are required by the Guide Specification to have an input resistance that does not exceed 300 ohms. Because of this constraint, the standard controller can drive up to two function modules in the controller output loop.

b. **Loop Driver.** The loop driver function module is externally powered and can drive up to an 800 ohm output load resistance. Loop drivers (sometimes referred to as loop isolators) have a characteristic input resistance that is less than 250 ohms. It is useful in an application where more than two devices are required in a controller output loop. In this type of application, only one of the devices and a loop driver function module should be connected directly to the controller output. The other two devices should be connected to the loop driver output. Use of the loop driver is illustrated in the controller TC-XX01 output loop in TM Figure 4-22A (Schematic For DX Coil Single-Zone HVAC System).

Loop drivers are also useful in an application where there is a relay contact in the control loop circuit. The loop driver can be used to isolate the contact from other devices in the circuit so that when the contact is open, current can still flow through to the other devices in the circuit. This is also illustrated in TM Figure 4-22A.

7. **Input and Output Loop Variations.**

a. **General.** The Technical Manual contains specific standard control loop configurations. In special applications or modifications, it may be necessary to modify the design of a standard loop or design a loop from scratch. Proper performance of special application control loops can be ensured by observing the following guidelines and constraints:

- relay contacts must be isolated from the circuit using a loop isolator.
- control panel DC power supply = 24 VDC

- function module input resistance = 300 ohms
- transmitter output resistance = 600 ohms
- controller input resistance = 250 ohms
- controller output resistance = 600 ohms
- loop isolator input resistance = 250 ohms
- loop isolator output resistance = 800 ohms
- resistance of 18 gage copper wire = 6.4 ohms per 1000 ft.

b. **Methods for Calculating Output Resistance.** To better understand input/output resistance-matching concepts, the following discussion is provided. In Figure 4-14, the 4-20 mA signal from a temperature transmitter is used as an input to two different controllers. To ensure the temperature transmitter's ability to supply a full 20 mA through the output loop load resistance imposed by the two controllers requires consideration of the electrical characteristics of the transmitter and the total resistance of the loop ($R_1 + R_2$). It is safe to assume that the temperature transmitter requires a liftoff voltage (V_{min}) of 12 VDC. We know that the control panel power supply provides 24 VDC (V_{PS}). The maximum loop resistance ($R_1 + R_2$) through which a transmitter can supply 20 mA can be calculated using Equation 4-16.

$$R_1 + R_2 = \frac{V_{PS} - V_{\text{min}}}{0.020\ A} \qquad \text{Eq. 4-16}$$

$$R_1 + R_2 = 600 \text{ ohms}$$

If $R_1 = R_2$, the input resistance of each controller cannot exceed 300 ohms.

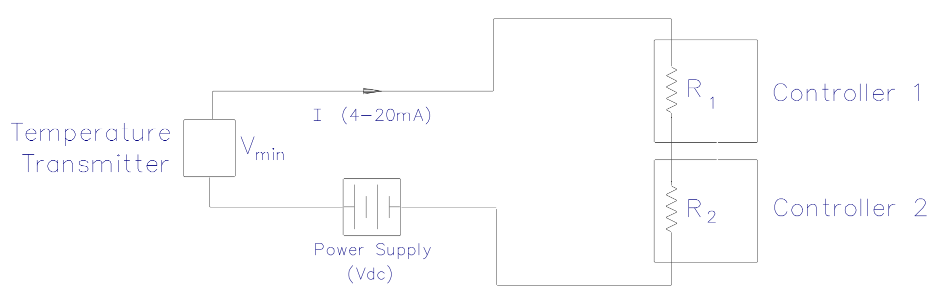


FIGURE 4-14. TRANSMITTER LOOP OUTPUT LOAD RESISTANCE.

Figure 4-15 illustrates a situation in which the load resistances in a controller's output loop should be checked. Here the controller is required to drive two I/P transducers. It must provide sufficient output power to produce a full 20 mA signal so that the actuators, through the I/P transducers, may be driven full stroke. In the example, the controller's output load resistance rating (R_L) must exceed the series combination of the I/P transducer resistances (R_1 and R_2):

$$R_L > R_1 + R_2$$

This method of computing output resistance differs from the preceding method because the power source used to drive the controller's output is internal to the controller.

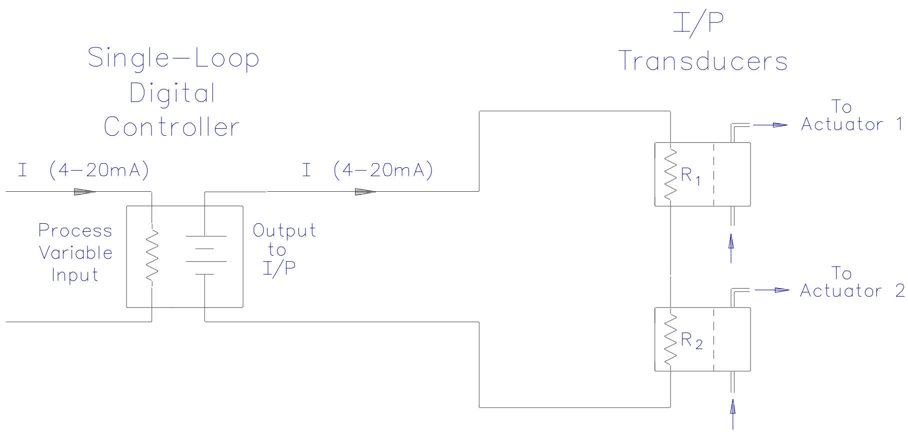
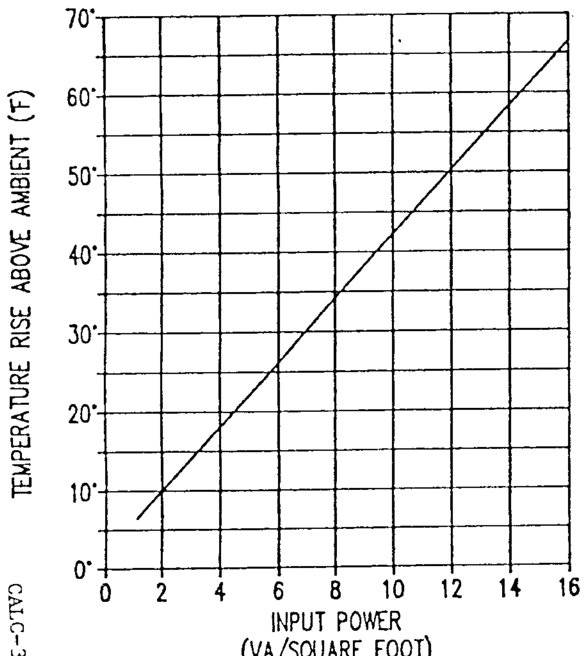


FIGURE 4-15. CONTROLLER OUTPUT LOOP LOAD RESISTANCE.

H. STANDARD CONTROL PANEL HEAT RISE CALCULATION.

A sample heat rise calculation for a standard control panel is shown on the next page.

ENCLOSURE TEMPERATURE RISE CALCULATIONS



TEMPERATURE RISE OF HOFFMAN STEEL GASKETED ENCLOSURES
(INFORMATION FROM HOFFMAN BULLETIN A-85)

CALC-37

SINGLE LOOP CONTROLLERS	5 EA @ 9.0 VA	=	45.0 VA
TIME CLOCK	1 EA @ 4.0 VA	=	4.0 VA
SWITCH & PILOT LIGHT LAMPS	12 EA @ 0.5 VA	=	6.0 VA
FUNCTION MODULES	2 EA @ 2.0 VA	=	4.0 VA
POWER SUPPLY	1 EA @ 40.0 VA	=	40.0 VA
RELAYS	11 EA @ 1.4 VA	=	15.4 VA
POWER CONDITIONER	1 EA @ 6.0 VA	=	6.0 VA
TOTAL PANEL POWER			120.4 VA

HEAT INPUT TO CONTROL PANEL = TOTAL PANEL POWER X (100% – 75% EFFICIENCY)
= 120.4 VA X (25%)
= 30.1 VA

CONTROL PANEL SURFACE AREA = 2 X [(HEIGHT X WIDTH) + (HEIGHT X DEPTH) + (WIDTH X DEPTH)]
= 2 X [(30" X 24") + (30" X 12") + (24" X 12")]
= 2,736 SQUARE INCHES/144 SQUARE INCHES PER SQUARE FOOT
= 19 SQUARE FEET

INPUT POWER = HEAT INPUT TO CONTROL PANEL/CONTROL PANEL SURFACE AREA
= 30.1 VA/19 SQUARE FEET
= 1.58 VA PER SQUARE FOOT

CONTROL PANEL TEMPERATURE RISE = 7.5F (FROM TABLE)

5 PRECONSTRUCTION CONFERENCE CHECKLIST

A Preconstruction Conference is usually conducted on Corps projects. The purpose of the Preconstruction Conference is to inform the contractor of the Corps' new concept of procurement of HVAC control systems as described in CEGS 15950. A DPW may also want to consider having a conference. The QV personnel should be aware that in the past, control systems were specified according to a performance-based criteria with actual design details left to the contractor. By using CEGS 15950, the control systems are now to be designed by the Army and details on the drawings and specifications are included. The contractors may not be familiar with this concept and should be informed to help eliminate confusion or misunderstandings.

The QV personnel should inform contractors that to maintain uniformity, no deviations from the design would be accepted. The QV personnel should give an overview of the concepts and design to the contractors. The overview should include:

[] Shop drawings submitted as a complete package

[] Off-season testing and controller tuning needs to be done

[] Coordination of controller tuning with final air and water balance

[] Test instruments to be utilized and calibration dates

[] Commissioning and PVT procedures required

[] Dampers may not be the same size as ductwork

[] Persons to attend training

[] Reports to be provided

[] Coordination with EMCS specification

[] Discuss coordination with other sections of the specifications containing valves, ...
dampers, control logic, etc.

6 SUBMITTAL REVIEW

GENERAL

This section deals with conducting reviews of the submittals for the standard HVAC control systems. Submittals are the documents which the contractor supplies to the Government that provide information about the work the contractor is going to do or has done, and provides information about the design, construction, commissioning, operation, and maintenance of the system. The Corps Field Office engineer usually does the Submittal Review, but the designer is often involved. A DPW usually will have a Contracting Officer to confirm the receipt of Submittals but probably would consult the designer and technicians about acceptance. QV personnel can use the Submittal Review Checklist to perform review.

OVERVIEW OF SUBMITTAL REVIEW

Significant effort has been expended to design and specify a coordinated set of system documentation. Under these specifications, the required contractor-submitted documents for standard HVAC control systems will more closely resemble shop drawings than the control drawings submitted in the past. QV personnel will be responsible for reviewing the submitted documents. These documents will be submitted, reviewed, and approved during different stages of the project, thus requiring coordination between all parties involved. A good review of the submitted documents is essential to help ensure that a fully functional and correctly constructed, installed, commissioned, and operating system is delivered to the user. A good review of the documents will also help reduce the likelihood of contractual problems arising later in the project. It is important to note that, once the submittals are approved, the contractor is free to install the system according to the approved documents. If deviations are overlooked during the submittal review, correcting them later may be difficult. The submittals that QV personnel will have to review are:

- Shop Drawings
- Equipment Catalog Cuts
- Calculations
- Sequence of Operation
- Site Testing Procedures
- Site Testing Report
- Commissioning Procedures
- Commissioning Report
- Performance Verification Testing Procedures
- Performance Verification Test Report
- Operating and Maintenance Manuals
- Qualified Service Organizations List
- Training Course Documentation

SUBMITTAL REVIEW CHECKLIST

SD-01, DATA

[ ] EQUIPMENT DATA
- [ ] in booklet form
- [ ] indexed to unique identifiers
- [ ] data shows compliance with contract specifications
- [ ] bill of material included
- [ ] see Inspection Checklist for device specifications

[ ] TRAINING
- [ ] Directed toward operation and maintenance
- [ ] Training Manual
  - [ ] one training manual for each trainee
  - [ ] two additional training manuals
  - [ ] agenda
  - [ ] defined objectives for each lesson
  - [ ] detailed description
  - [ ] submitted 60 days prior to course
- [ ] Audiovisual material
  - [ ] two copies furnished

SD-04, DRAWINGS (SHOP DRAWINGS)

[ ] GENERAL
- [ ] Submitted as a complete package
- [ ] Drawings use abbreviations, symbols, nomenclature, and identifiers as shown on the contract drawings
- [ ] Drawings on 34 inch by 24 inch sheets
- [ ] All control devices on drawings have a unique identifiers

[ ] DRAWING INDEX

[ ] LIST OF SYMBOLS

[ ] SERIES OF DRAWINGS FOR EACH HVAC SYSTEM
- [ ] Schematic
- [ ] Ladder Diagram
- [ ] Equipment Schedule
- [ ] Wiring Diagram
  - [ ] Shows interconnection of conductors and cables to HVAC control panel terminal blocks
  - [ ] Shows connection to terminals of starters and packaged equipment
  - [ ] Conductors labeled
  - [ ] Sources of power for HVAC control equipment shown

- [ ] Shows calculation for Volt-Amp load
- [ ] Shows Volt-Amp rating of power supply

[ ] Bill of Material (Equipment List) showing manufacturer and model number

[ ] Control Panel Arrangement
- [ ] Nameplate legends shown
- [ ] Fabrication details shown
- [ ] Panel temperature rise calculations
- [ ] Interior door front view
- [ ] Interior door rear view
- [ ] Back panel layout view
- [ ] Terminal block layout

[ ] Sequence of Operation
- [ ] Language and format of contract specifications
- [ ] Control devices referred to by unique identifier
- [ ] Operational deviations from the specified sequences approved by the Contracting Officer

[ ] Valve Schedules
- [ ] Unique Identifier for each valve
- [ ] size
- [ ] flow coefficient
- [ ] pressure drop at specified flow rate
- [ ] close off pressure data
- [ ] spring range
- [ ] positive positioner range
- [ ] actuator size
- [ ] clearance requirements
- [ ] valve dimensions
- [ ] leakage rate

[ ] Damper Schedules
- [ ] unique identifier for each damper
- [ ] unique identifier for each damper actuator
- [ ] size
- [ ] maximum expected velocity thru damper
- [ ] maximum expected leakage rate at the operating static pressure differential
- [ ] actuator torque
- [ ] calculation of actuator torque requirement
- [ ] direction of blade rotation
- [ ] actuator spring ranges
- [ ] actuator operation rate
- [ ] positive positioner range
- [ ] location of actuators
- [ ] location of damper end switches

- [ ] arrangement of multisection dampers
- [ ] method of connecting dampers, actuators and linkage
- [ ] orientation of axis and frame of dampers

[ ] Compressed Air Station Schematic
- [ ] compressor
- [ ] motor
- [ ] starter
- [ ] isolators
- [ ] manual bypasses
- [ ] tubing sizes
- [ ] drain piping and traps
- [ ] dryers
- [ ] pressure reducing valves
- [ ] calculation of air consumption by devices connected to the compressed air station
- [ ] calculation of starts per hour
- [ ] calculation of running time
- [ ] calculation of compressed air dew point at 20 psig
- [ ] ASME Air-Storage Tank Certificate
- [ ] air compressor horsepower and power requirements

SD-06, INSTRUCTIONS

[ ] Service Organization
- [ ] Name and phone number

SD-09, REPORTS

[ ] SITE TESTING PROCEDURES
- [ ] Identifies items to be tested
- [ ] Describes each test
- [ ] test equipment to be used
- [ ] manufacturer and model number of test equipment
- [ ] date of calibration of test equipment
- [ ] accuracy of calibration of test equipment

[ ] SITE TESTING DATA
- [ ] original copies of data gathered during tests

[ ] PERFORMANCE VERIFICATION TEST PLANS AND PROCEDURES
- [ ] indexed
- [ ] booklet form
- [ ] submitted 60 days before scheduled test

[ ] PERFORMANCE VERIFICATION TEST REPORT
- [ ] indexed
- [ ] booklet form

[ ] submitted 30 days after test

SD-18, RECORDS (COMMISSIONING REPORT)

[ ] include controller configuration checksheet with all final values
[ ] calibration data for all control devices

SD-19, OPERATION AND MAINTENANCE MANUALS

Note: Operation and Maintenance manuals can be supplied in a common volume

[ ] OPERATION MANUAL
- [ ] booklet form
- [ ] indexed
- [ ] startup, operation, and shutdown (Sequence of Operation) of HVAC control system
- [ ] detail drawings (shop drawings)
- [ ] equipment data
- [ ] configuration checksheet for each controller
- [ ] manufacturer operation manuals

[ ] MAINTENANCE MANUAL
- [ ] booklet form
- [ ] indexed
- [ ] maintenance checklist for HVAC controls
- [ ] spare parts data
- [ ] recommended maintenance tool kit
- [ ] recommended repair methods

[ ] COMMISSIONING PROCEDURES
- [ ] submitted 60 days prior to commissioning
- [ ] booklet form
- [ ] indexed
- [ ] for each control device
- [ ] instructions for how to set up devices
- [ ] specific procedures for each HVAC control system
- [ ] specific procedures for each terminal unit control
- [ ] reflect language and format of this specification
- [ ] refer to device by their unique identifiers
- [ ] instructions on how to configure controllers
- [ ] include controller configuration checksheet

7 EQUIPMENT SUBMITTAL REVIEW AND QUALITY VERIFICATION OF INSTALLATION

GENERAL

This section deals with two issues concerning the control equipment: the review of equipment catalog cuts to confirm adherence with the Corps specifications, and the inspection (quality verification) to confirm that the control system has been installed according to the Corps specifications, the equipment catalog cut sheets, or the equipment user manuals.

SITE TESTING

Depending on the version of the CEGS 15950 used in the contract, the contractor may be required to conduct site testing of the control equipment. This site testing is different than the commissioning and performance verification tests. Site testing should be done during installation and would include testing the pneumatic tubing for leaks, and testing electrical wiring for continuity, grounds, and shorts. The contractor should submit Site Testing Procedures that identify and clearly describe the tests to be performed. Upon completion, a Site Testing Report should be submitted to the Government for approval.

CHECKSHEETS

Two checksheets have been produced that cover the specifications for panel and field equipment. Brackets are provided to allow the user to check whether a particular specification has been met. Some specifications have one set of brackets, some have two. The first set of brackets is to be used for checking that the equipment meets the specifications during the submittal review. The second bracket is to be used for checking the specification in the field. The checksheets are basically a reproduction of CEGS 15950 in a form more easily checked off when a piece of equipment meets a particular specification.

FIELD EQUIPMENT INSPECTION CHECKLIST

The following checklist covers field devices and was developed from CEGS 15950. Some items need to be checked only during the Submittal Review stage; others need to be checked only during the installation inspection of equipment stage, and some need to be checked during both stages. The brackets indicate when the check should be done, first column for Submittal Review, second column for inspection. For reference, the CEGS section numbers are included as part of the heading. This checklist is intended to be used for bookkeeping purposes and not as the contract document.

1.2 GENERAL REQUIREMENTS

1.2.1 Standard Products

[ ] Equipment has been in commercial or industrial use for over 2 years or field operation of over 6000 hours

1.2.2 Identical Items

[ ] [ ] Assemblies, parts, and components of the same classification, as specified in PART 2 - Products, are identical

1.2.3 Nameplates, Lens Caps, and Tags

[ ] [ ] Pilot light lens caps are labeled as shown on contract drawings
[ ] Equipment tags are labeled with unique identifiers as shown
[ ] Lens caps and tags have engraved or stamped characters
[ ] Name plates on HVAC control panel are mechanically attached
[ ] Plastic or metal tags are attached to each field mounted device either mechanically, with chain, or with wire
[ ] Air Flow Measurement Stations have tag showing:
- [ ] 1. Flow rate change for signal output range
- [ ] 2. Duct size
- [ ] 3. Identifier as shown

1.2.6 Power Line Surge Protection

[ ] [ ] Equipment connected to ac circuits protected according to IEEE* C62.41

1.4 DELIVERY AND STORAGE

[ ] Products have been, or are being, protected from weather, humidity, temperature variations, dirt, dust and other contaminants
[ ] Dampers have been stored to safely maintain seal integrity, blade alignment, and frame alignment

PART 2 PRODUCT

2.1 GENERAL EQUIPMENT REQUIREMENTS

2.1.1 Electrical and Electronic Devices

[ ] [ ] All electrical, electronic, electro-pneumatic devices not mounted in the HVAC control panel are mounted in NEMA 1 enclosures, unless otherwise shown

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*IEEE = Institute of Electrical and Electronics Engineers

2.2 MATERIALS

2.2.1 Tubing

2.2.1.1 Copper

[ ] Installed with sweat fittings and valves
[ ] Conforms to ASTM B 88

2.2.1.2 Plastic

[ ] Installed with barbed fittings and valves
[ ] ASTM D 635 burn testing
[ ] UL 94 V-2 flammability classification
[ ] ASTM D 1693 stress cracking testing

From 3.2.10 Execution

[ ] Pneumatic lines are not exposed to outside air
[ ] Pneumatic lines run parallel to building lines
[ ] Tubing external to the mechanical\electrical spaces is soft copper
[ ] Tubing internal to the mechanical\electrical spaces is plastic in raceway or copper supported every 6 feet vertically and 8 feet horizontally, neatly run, and labeled at source and final connection
[ ] Tubing connected to liquid and steam line sensing elements is copper or series 300 stainless steel
[ ] Tubing connected to duct sensing elements is plastic
[ ] Tubing in concrete installed in rigid conduit
[ ] Tubing in insulated walls installed in conduit

2.2.1.3 Stainless Steel

[ ] Installed with stainless steel compression fittings
[ ] [ ] Conforms to ASTM A 269

2.2.2 Wiring

2.2.2.1 Terminal Blocks

[ ] Insulated and modular
[ ] Suitable for rail mounting
[ ] Feed-through with recessed captive screw for clamping

2.2.2.2 Control Wiring for 24 Volt Circuits

[ ] [ ] 14 AWG minimum
[ ] Rated for 300 volt service

2.2.2.3 Wiring for 120-Volt Circuits

[ ] [ ] 16 AWG minimum
[ ] Rated for 600-volt service

2.2.2.4 Analog Signal Wiring Circuits

[ ] [ ] Not less than 20 AWG within control panels
[ ] Rated for 300 volt service

2.2.2.5 Instrumentation Cable

[ ] [ ] 18 AWG stranded copper minimum
[ ] [ ] Minimum 2-inch lay for twisted pairs
[ ] [ ] Pairs are 100 percent shielded
[ ] [ ] 300-volt insulation
[ ] [ ] Each pair has 20 AWG tinned copper drain wire
[ ] [ ] Individual pairs have an overall insulation
[ ] [ ] Cables have an overall aluminum-polyester or tinned-copper cable-shield tape
[ ] [ ] Cables have an overall 20 AWG tinned-copper cable drain wire
[ ] [ ] Cables have overall cable insulation
[ ] Shield is grounded at the control panel only

2.2.2.6 Wiring Duct

[ ] [ ] Slotted sides
[ ] [ ] Snap-on covers

2.3 ACTUATORS

2.3.1 General

[ ] [ ] Fail to spring-return position as shown upon loss of signal or power
[ ] [ ] Visible position indicator
[ ] [ ] Rated at 25 psig operating pressure
[ ] 60 Second full stroke response time
From 2.1.3
[ ] Operable between 35 and 150E F
From Section 3.2 Control System Installation
[ ] Pneumatic actuator final connection is unsupported plastic tubing at least 12 inches long
[ ] Pneumatic actuator has proper range pressure gauge installed
[ ] Pneumatic actuator has positive positioner installed

2.3.2 Damper Actuators

[ ] Adjustable stop to limit travel in the power stroke direction
[ ] Mounting and connecting hardware provided
From Section 3.2 Control System Installation
[ ] Not installed in the air stream
[ ] Multiple actuators operating a common damper shall be connected to a common drive shaft

2.3.3 Valve Actuators

[ ] Provide 125% of power to actuate to full range

2.3.4 Positive Positioners

[ ] Mechanical feedback
[ ] Adjustable starting point

[ ] Adjustable operating range
From 2.1.3
[ ] Operable between 35 and 150E F

2.4 AUTOMATIC CONTROL VALVES
2.4.1 Valve Assembly
[ ] [ ] Stainless steel stem and stuffing box
[ ] Neck extends to clear insulation
[ ] Leakage not to exceed 0.01% of rated Cv

2.4.2 Butterfly Valves
[ ] Suitable for dead end service
Able to modulate to full closed position
[ ] Carbon steel body
[ ] Noncorrosive discs
[ ] Stainless steel shaft supported by bearings
[ ] [ ] Manual means of operation separate from the actuator provided
[ ] EDPM seats suitable for minus 20 to 250E F

2.4.3 Two-way Modulating Valves
[ ] Equal percentage flow characteristics

2.4.4 Three-way Modulating Valves
[ ] Linear flow control with constant total flow throughout movement

2.4.6 Chilled - Water, Condenser - Water, and Glycol Service Valves
[ ] Brass or bronze for valve bodies 1-1/2 inches and smaller
[ ] Brass, bronze, or iron for valve bodies 2 to 3 inches
[ ] 2 inch valve bodies have threaded ends
[ ] 2 1/2 inch and 3 inch valve bodies have flanged - end connections
[ ] Internal valve trim is brass, bronze or 316 stainless steel
[ ] Valves 4 inches or larger are butterfly type

2.4.7 Hot Water Service Valves below 250E F
[ ] Brass or bronze with threaded or union ends for valve bodies 1-1/2 inches and smaller
[ ] Brass, bronze, or iron for 2 to 3 inch valve bodies
[ ] 2 inch valve bodies have threaded ends
[ ] 2 to 3 inch valve bodies are brass, bronze, or iron
[ ] 4 inch or larger valve bodies are iron
[ ] Flanged end connections for valve bodies 2-1/2 inch and larger
[ ] C_v between 100% and 125% of that shown on schedule
[ ] Type 316 stainless steel for operation over 210E F

2.4.8 Steam Service Valves
[ ] Brass or bronze with threaded or union ends for valve bodies 1-1/2 inches and smaller
[ ] Brass, bronze, or iron for 2 to 3 inch valve bodies
[ ] 2 inch valve bodies have threaded ends

[ ]		2 to 3 inch valve bodies are brass, bronze, or iron
[ ]		4 inch or larger valve bodies are iron
[ ]		Flanged end connections for valve bodies 2-1/2 inch and larger
[ ]		Valve trim Type 316 stainless steel
[ ]		C_v not less than shown on schedule, or greater than next larger size

2.4.9 High - Temperature Hot - Water Valves above 250 deg.F
[ ] [ ]		Normally Closed valve and actuator combination
[ ]		Carbon steel, globe type bodies with welded end for valves 1 inch and larger
[ ]		1 inch and smaller valves have socket - weld ends
[ ]		Valve bodies rated ANSI Class 300, ASME B16.34
[ ]		Internal valve trim Type 316 stainless steel
[ ]		Polytetrafluoroethylene (PTFE) packing
[ ]		C_v between 100% and 125% of that shown on schedule
From 3.2
[ ]		Dielectric isolation provided and installed, if required

**2.5		DAMPERS**
**2.5.1		Damper Assembly**
[ ] [ ]		Single damper section is no higher than 72 inches
[ ] [ ]		Blades no longer than 48 inches
[ ] [ ]		Blades no wider than 8 inches
[ ] [ ]		Frames not less than 2 inches wide
[ ] [ ]		Steel construction or other materials where shown (corrosive areas for example)
[ ] [ ]		Flat blades have folded edges
[ ] [ ]		BladeCoperating linkages are located within the frame, no blade connecting devices in the same section are located in the air stream
[ ]		Damper axles minimum 0.5 inch plated steel rods
[ ] [ ]		Vertically mounted blades are supported by thrust bearings
[ ] [ ]		Pressure drop not to exceed 0.04 iwg at 1000 fpm when wide open
[ ]		Testing in accordance with AMCA 500

**2.5.1.1	Operating Links**
[ ] [ ]		Adjustable rod lengths
[ ] [ ]		Brass, bronze, zinc - coated, or stainless steel operating links
[ ] [ ]		Brass, bronze, or stainless steel joints and clevises
[ ] [ ]		Crank arm adjustment controls the open and closed position of the damper

**2.5.1.2	Damper Types**
[ ] [ ]		Dampers are parallel blade type

**2.5.2		Outside- Air, Return - Air, and Relief - Air Dampers**
[ ]		Transitions and blank-off plates are provided for fitting damper to duct as shown or required
[ ] [ ]		Blades have interlocking edges with compressible seals at points of contact
[ ] [ ]		Jamb seals are provided on channel frames to minimize leakage
[ ]		Leakage less than 20 cfm per sqft at 4 iwg static pressure when closed

[ ] Rating not less than 2000 fpm

2.5.3 Mechanical and Electrical Space Ventilation Dampers

[ ] Leakage less than 80 cfm per sqft at 4 iwg static pressure when closed
[ ] Rating not less than 2000 fpm

2.5.4 Smoke Dampers

[ ] Meets NFPA 90A Class II leakage requirements of UL 555S
[ ] Rating not less than 2000 fpm

2.5.5 Damper End Switches

[ ] Installed where shown or as required
[ ] [ ] Shown on schematics and ladder diagrams
[ ] [ ] Switch is hermetically sealed
[ ] [ ] Trip lever
[ ] [ ] Over - travel mechanism
[ ] Trip lever is aligned with damper blade

2.7 INSTRUMENTATION

2.7.2 Temperature Instruments

2.7.2.1 RTD's

[ ] Platinum internal sensing element
[ ] 100 ohm, 3-wire
[ ] Accuracy of plus or minus 0.1% at 32E F
[ ] Encapsulated in epoxy, stainless steel, anodized aluminum or copper
[ ] Integral transmitter unless otherwise shown

2.7.2.2 Continuous - Averaging RTD

[ ] Furnished with enclosure and RTD Transmitter that matches RTD resistance range (100ohm, 1000ohm, etc.) integrally mounted, unless otherwise shown
[ ] (from 3.2.5) Total element length is equal to 1 linear foot for every square foot of duct cross sectional area
[ ] Accuracy of plus or minus 1.0E F
[ ] Sheath is bendable copper
[ ] Installed in serpentine fashion

2.7.2.3 RTD Transmitter

[ ] Accepts a 3-wire 100 ohm RTD input
[ ] 2-wire, loop powered
[ ] [ ] Integrally mounted with its associated RTD
[ ] Provides a 4-20 mAdc output corresponding to the range as shown on the schedule
[ ] Output error not to exceed 0.1% of span
[ ] Offset and span adjustments

2.7.3 Relative - Humidity Instruments

[ ] 0 to 100% range

[ ] Operable between 25 and 130E F

[ ] 2-wire, loop powered transmitter provided and mounted at the sensor location

[ ] Accuracy of plus or minus 2% RH between 20 and 90% RH

[ ] Accuracy of plus or minus 3% RH between 90 and 100% RH

[ ] 4-20 mAdc output

[ ] Offset and span adjustments

2.7.4 Electronic Air-flow Measuring Stations and Transmitters

From 1.2.3

[ ] Air Flow Measurement Stations have tag showing:

  [ ] Flow rate change for signal output range

  [ ] Duct size

  [ ] Identifier as shown

2.7.4.1 Stations

[ ] Required for velocity measurements below 700 fpm

[ ] Rated for flows up to 5000 fpm

[ ] Flanged sheet-metal casing containing sensing element array

[ ] Sensor quantity and pattern adhere to ASHRAE-03 and SMACNA-07 (generally 16 sensors, spaced as referenced, are installed in the stations, some problems have been experienced with the number of sensors manufactures install for stations specified for duct work smaller than 4 square feet)

[ ] Pressure drop not to exceed 0.08 iwg at 2000 fpm air flow

[ ] RTD or thermistor type velocity sensors

[ ] Accuracy of plus or minus 3% over 125 to 2500 fpm

2.7.4.2 Transmitters

[ ] 2-wire, loop-powered device

[ ] Temperature compensation to output linear 4-20 mAdc signal corresponding to velocity range as shown on schedule

[ ] Accuracy of 0.5% of range

[ ] Offset and span adjustments provided

2.7.5 PITOT-TUBE AIR-FLOW MEASURING STATION

2.7.5.1 Stations

[ ] Required velocity pressure measurement is above 700 fpm (CANNOT be used if below 700 fpm)

[ ] Flanged sheet-metal casing containing sensing element array and flow straightening vanes

[ ] Sensing elements are multiple pitot-tube type with averaging manifolds

[ ] Sensor quantity and pattern adhere to ASHRAE-03 and SMACNA-07 (generally 16 sensors, spaced as referenced, are installed in the stations, some problems have been experienced with the number of sensors manufactures install for stations specified for duct work smaller than 4 square feet)

[ ] Maximum 0.08 iwg drop at 2000 fpm
[ ] Accuracy of plus or minus 3% over range of 500 to 2500 fpm

2.7.5.2 Transmitters
[ ] 2-wire, loop-powered device
[ ] Output linear 4-20 mAdc signal corresponding to velocity range as shown on schedule
[ ] Square root extraction of signal
[ ] Accuracy of 0.25% of range
[ ] Offset and span adjustments provided

2.7.6 Differential Pressure Instruments
[ ] [ ] Static pressure sensing element
[ ] [ ] Unit is pressure transmitter with integral sensing element
[ ] Rated for 300% of operating pressure
[ ] Accuracy is plus or minus 2 percent of full scale
[ ] 2-wire, loop-powered device
[ ] Output is linear 4-20 mAdc scaled to the required pressure measurement
[ ] Offset and span adjustments are provided
[ ] [ ] 0 to 2 inch water gauge differential pressure sensor is provided as required for VAV system duct static pressure measurements

From Section 3.2 Control System Installation
[ ] Static pressure element installed 2/3 of the distance from the supply fan to the end of the duct with the greatest pressure drop

2.7.7 Thermowells
[ ] [ ] Series 300 stainless steel
[ ] [ ] Threaded brass plug and chain
[ ] [ ] 2-inch lagging neck
[ ] [ ] Extension type well
[ ] [ ] Inside diameter and insertion length are correct for the application and the RTD to be installed

2.7.8 Sunshields
[ ] Located as shown on the drawings
[ ] Sunshield location and installation protect the outdoor air temperature sensing element from direct radiation of the sun
[ ] Ventilation is provided
[ ] Galvanized-metal rainshield projecting over the face of the sunshield is provided
[ ] [ ] Finish is painted white or unpainted aluminum

2.8 THERMOSTATS
[ ] [ ] Setpoint adjustable to plus or minus 10E F of setpoint shown on schedule
[ ] Electric or electronic
[ ] Sensing element installed 5 feet above floor

2.8.2 Nonmodulating Room Thermostats

[ ] Locking cover
[ ] Single-pole double throw type
[ ] Maximum differential of 5E F
[ ] Manual switch is provided if required by the application

2.8.3 Microprocessor-based Room Thermostats

[ ] Built-in keypad
[ ] Continuous display of time, day, and temperature
[ ] Two separate temperature setback intervals per day
[ ] Temporary override
[ ] Manual override
[ ] 1 year battery backup of memory
[ ] Maximum setpoint differential of 2E F.

2.8.4 Modulating Room Thermostats

[ ] Adjustable throttling range of 4 to 8E F
[ ] Locking covers
[ ] One output, or two outputs in unison, or two outputs in sequence depending on the application

2.8.5 Nonmodulating Capillary Thermostats and Aquastats

[ ] [ ] Capillary length is at least 5 feet
[ ] Thermostat differential adjustable from 6 to 16E F
[ ] Aquastat differential fixed at 10E F

2.8.6 Low-Temperature-Protection Thermostats

[ ] NO and NC contacts
[ ] 20 ft element
[ ] Responds to coldest 18-inch segment
From Section 3.2 Control System Installation
[ ] Thermostats are provided to sense the temperature of each 20 square feet of coil face area, or fraction thereof
    [ ] Installed at the location shown
    [ ] Element(s) are installed in a serpentine pattern

2.9 PRESSURE SWITCHES AND SOLENOID VALVES

2.9.2 Differential Pressure Switches

[ ] Differential adjustment of 20 to 40% of span

2.9.2 Differential Pressure Switches

[ ] Adjustable diaphragm-operated device
[ ] Two SPDT contacts
[ ] Range 0.5 to 6.0 iwg
[ ] Max differential of 0.15 iwg at low end
[ ] Max differential of 0.35 iwg at high range
    [ ] (3.3.1) installed as shown and according to manufacturer's recommendations

2.9.3 Pneumatic Electric (PE) Switch

[ ] [ ] Adjustable setpoint of 3 to 20 psig
[ ] [ ] Adjustable differential of 2 to 5 psig
[ ] (3.3.1) installed as shown and according to manufacturer's recommendations

2.9.4 Solenoid-Operated Pneumatic (EP) Switch

[ ] Outer body is cast-aluminum
[ ] [ ] 3/8 inch NPT threaded connections
[ ] Rate for 50 psig for 25 psig operating control systems
[ ] Rate for 150 psig for 25 to 100 psig operating control systems

2.10 INDICATING DEVICES

2.10.1 Thermometers

From 3.2.9
[ ] [ ] Thermometers and sensing elements in liquid piping systems are installed in stainless steel thermowells

2.10.1.1 Piping System Thermometers

[ ] [ ] Permanently stabilized glass tube with indicating fluid column
[ ] [ ] Inner face is white with black numbers
[ ] [ ] 9 inch scale
[ ] [ ] Piping system thermometers have rigid stems with straight, angular, or inclined pattern
[ ] Installed and positioned to be easily readable

2.10.1.2 Piping System Thermometer Stems

[ ] Expansion heads to prevent breakage

2.10.1.3 Air Duct Thermometers

[ ] [ ] 45 degree adjustable duct flange
[ ] Installed and positioned to be easily readable

2.10.1.4 Averaging Thermometers

[ ] [ ] 3-1/2 inch (nominal) dial
[ ] Installed and positioned to be easily readable

2.10.1.5 Accuracy

[ ] Accuracy of plus or minus 1% of scale

2.10.2 Pressure Gauges

[ ] 2 inch nominal size
[ ] Back connection
[ ] Black legend on white background
[ ] Accuracy of plus or minus 3% of scale
[ ] Meet ASME B40.1

From 3.2 Installation

[ ] Snubbers are provide for gauges installed in piping systems subject to pulsations
[ ] [ ] Gauges for steam service have pigtail fittings with cock
[ ] Installed and positioned to be easily readable

2.10.2.1 Pneumatic Actuator Gauges

[ ] [ ] Outer scale is 3 to 15 psig
[ ] [ ] 1 psig graduations
[ ] Installed and positioned to be easily readable

2.10.2.2 Air Storage Tank and Filter and Dryer Gauges

[ ] [ ] 0 to 160 psig scale
[ ] [ ] 2 psig graduations
[ ] Installed and positioned to be easily readable

2.10.2.3 Hydronic System Gauges

[ ] Installed where shown on drawings
[ ] Installed and positioned to be easily readable

2.10.2.5 Low Differential Pressure Gauges

[ ] 4-1/2 inch nominal size
[ ] Zero point adjustment
[ ] Accuracy of plus or minus 2% of scale

2.15 Compressed Air Stations

2.15.1 Air Compressor Assembly

[ ] [ ] High pressure compressing unit with electric motor
[ ] [ ] Compressor is equipped with:
  [ ] motor with belt guard
  [ ] operating pressure switch
  [ ] safety relief valves
  [ ] gauges
  [ ] intake filter
  [ ] intake silencer
  [ ] combination type magnetic starter with undervoltage and thermal overload protection for each circuit
  [ ] steel base mounted on the storage tank
[ ] [ ] Tank is provided with an automatic condensate drain trap with manual override feature

From Section 3.2 Installation

[ ] [ ] Foundation and housekeeping pads provided
[ ] [ ] Mounted on vibration eliminators
[ ] [ ] Flexible pipe connector used to connect air line to tank

3.1 GENERAL INSTALLATION CRITERIA

[ ] [ ] Dielectric isolation has been provided where dissimilar metals are used for connection or support

[ ] [ ] Penetrations through and mounting holes in the building exterior have been made watertight
[ ] [ ] Installation clearance requirements for access to control system devices for maintenance, calibration, removal, and replacement have been provided.
[ ] [ ] Access space is provided between coils, and to mixed air plenums
[ ] [ ] Control system installation does not interfere with clearance requirements for mechanical and electrical system maintenance

3.1.1 Device Mounting Criteria
[ ] [ ] Manual valves for purging, shutoff, equalization, and calibration have been provided for control devices installed in piping or ductwork
[ ] [ ] Strap on sensing elements have not been used except as specified

3.2.1 Wiring Criteria
[ ] [ ] Low voltage wiring and other wiring external to the control panel is run in metallic raceway
[ ] [ ] Wiring has not been spliced between the control panel and the controlled devices
[ ] [ ] Instrumentation grounding is installed
[ ] [ ] Cables and conductor wires are tagged at both ends
[ ] [ ] Tag identifiers are as shown on the shop drawings

CONTROL PANEL INSPECTION CHECKLIST

The following checklist covers the standard HVAC control panel and was developed from CEGS 15950 and the Construction Drawings as released by Savannah District. Some items only need to be checked during the Submittal Review stage, others only need to be checked during the installation inspection stage, and some items need to be checked during both stages. The brackets indicate when the check should be done, first column for Submittal Review, second column for inspection. The checklist is inteded to be used for bookkeeping purposes and not as the contract document.

1. PANEL ENCLOSURE
[ ] [ ] NEMA 12 type (Panels usually will have a sticker noting the panel-type. A Catalog cut sheet should be included in the Equipment Data Booklet.)
[ ] [ ] Wall mounting brackets
[ ] [ ] Panel mounted a minimum of 2 in. from wall
[ ] [ ] Ventilation louvers installed on back of panel
[ ] [ ] Ventilation louver size 8 in. high, 9 1/2 in. wide
[ ] Temperature rise less than 20E F
[ ] Outside finish gray primer over phosphatized surface
[ ] [ ] Only bottom-entry tubing and electrical piping
[ ] [ ] Outside dimensions of panel 30 in. high, 24 in. wide, 16 in. deep
[ ] [ ] Single exterior door
[ ] [ ] Continuous hinged exterior door
[ ] [ ] Lockable exterior door
[ ] [ ] System nameplate on exterior door
[ ] [ ] Exterior door pocket

[ ] [ ] Exterior door gasketed
[ ] [ ] Continuous hinged interior door
[ ] [ ] Interior door dimensions 27 in. high, 21 in. wide
[ ] [ ] Distance from interior door to exterior door 1-5/8 in.
[ ] [ ] Interior back plate
[ ] [ ] Distance from interior door to terminal blocks 10-3/4 in.
[ ] [ ] Inside finish white enamel
[ ] [ ] Certification of temperature rise limit (Should be included in the Equipment Data Booklet or PVT.)

2. INTERIOR DOOR PILOT LIGHTS AND SWITCHES

[ ] [ ] Locations correct (Refer to the Interior Door Layout Drawing supplied in the contract drawings.)
[ ] [ ] Labeled correctly
[ ] [ ] Rectangular shape
[ ] Light emitting diode or neon lamp illumination
[ ] [ ] Reset switch is non-illuminating, momentary
[ ] [ ] Auto/Overide and Enable/Off switches are contact-maintained interlocked with separately illuminated sections.
[ ] [ ] Where split legends are used on lights, the sections are separately illuminated

3. SINGLE LOOP CONTROLLERS

[ ] [ ] Locations correct (Refer to the Interior Door Layout Drawing supplied in the contract drawings.)
[ ] [ ] Labeled correctly
[ ] [ ] Knockout holes and blankout plates installed where required
[ ] Microprocessor based single loop device
[ ] No contractor generated software
[ ] Meets CFR 47 Part 15 CFR of FCC code for Class A devices
[ ] Width 3.62 inches, height 3.62 inches
[ ] Field scalable process variable
[ ] Analog input for remote setpoint
[ ] Analog output with adjustable high and low end limits
[ ] Proportional control manual reset
[ ] AO Proportional, Integral, and Derivative control
[ ] AO Configurable to be DA or RA
[ ] Keyboard for entering control parameters
[ ] Display
    [ ] 3-1/2 digit
    [ ] 7-segment displays
    [ ] decimal point indication
    [ ] polarity indication
    [ ] show all parameters, setpoints, mode constants, process variable and output
    [ ] all values displayed in engineering units
[ ] Selection of either Auto or Manual for analog output
[ ] Selection of either RSP or LSP
[ ] Adjustable high-end and low-end limits for RSP and LSP

[ ] Ratio and Bias adjustment of RSP input
[ ] Selection of Operator-initiated self-tune, to modify P, I, D values.
[ ] Anti-reset wind-up feature
[ ] Two configurable independent SPDT output contacts
  [ ] both with option of being NO or NC
  [ ] one with option of being process variable activated
  [ ] one with option of being process variable deviation-from-setpoint activated
[ ] Configurable to power up in:
  [ ] manual with LSP control
  [ ] automatic with LSP control
  [ ] automatic with RSP control
[ ] Hysteresis adjustment of not less than 5% of PV span
[ ] Able to power analog output loop to 20 mA with a load of 600 ohms.
[ ] Capable of retransmitting PV to 20 mA at 600 ohms
[ ] 5-year battery backup of operating parameters or non-volatile memory
[ ] Powered by 120 Vac
[ ] Power consumption less than 20 watts
[ ] Electrical noise isolation between ac power line and
  [ ] PV input
  [ ] RSP input
  [ ] output signal
  [ ] not less than 100 db at 60 Hz common-mode rejection ratio
  [ ] not less than 60 db at 60 Hz normal-mode rejection ratio
[ ] Accuracy of plus or minus 0.30% of input span, plus or minus 1 digit
[ ] Selection of operator initiated manual tuning, from the front keyboard, for modification or elimination of each control mode value
[ ] Proportional-mode constant value adjustable from 0 to 200 percent of input signal range
[ ] Integral-mode constant value adjustable from 0 to 20 repeats per minute
[ ] Derivative-mode constant value adjustable from 0 to 5 minutes

4. LABELS

[ ] Mechanically affixed
[ ] Lettering of contrasting color
[ ] Lettering depth 1/64th inch depth

5. INTERIOR DOOR AIR PRESSURE GAGES (if required)

[ ] [ ] Locations correct (Refer to the Interior Door Layout Drawing supplied in the contract drawings.)
[ ] [ ] Labeled correctly
[ ] [ ] Knockout holes and blankout plates installed where required
[ ] [ ] Size - 2-1/2 inches
[ ] [ ] Back connected
[ ] [ ] Black legend on white background
[ ] [ ] 270 degree pointer travel
[ ] [ ] 3-15 psig outer scale range, 1 psig graduations
[ ] [ ] 0-100% inner scale range, 1% graduation
[ ] Accuracy plus or minus 3% of scale range - 0.36 psig for 3-15 psi

[ ] Meet ANSI B40.1

6. CURRENT-TO-PNEUMATIC TRANSDUCERS

[ ] 2-wire
[ ] convert 4-20mA to 3-15 or 15-3 psig
[ ] Field-reversible pneumatic output
[ ] Accuracy plus or minus 2% of full scale
[ ] Power consumption less than 0.5 watts
[ ] Input impedance not exceed 250 ohms
[ ] Air consumption less than 0.25 scfm
[ ] [ ] Location correct
[ ] [ ] Labeled correctly
[ ] [ ] Mounted on specified rails
[ ] [ ] Output piped to bulkhead fittings
[ ] [ ] Wired to terminal block
[ ] Two inch loop to accommodate I/P replacement

7. POWER LINE CONDITIONER

[ ] [ ] Location correct
[ ] Provides voltage regulation and noise rejection
[ ] Ferroresonant design
[ ] Sized for 125% of actual connected kva laod
[ ] Total harmonic distortion not exceed 3-1/2 % at full load

8. DC POWER SUPPLY

[ ] Provide a 24Vdc supply, regulation to 0.05% of output
[ ] Provide not less than 2 amperes
[ ] [ ] Input to power supply fused and protected from voltage surges and power-line transients according to IEEE 587.
[ ] [ ] Output of power supply shall be protected against overvoltages and short circuits
[ ] Power supply loading less than 1.2 amperes
[ ] [ ] Location correct

9. TIME CLOCK

[ ] 365-day programmable
[ ] Four independently timed circuits
[ ] Scheduling keypad
[ ] Alphanumeric display of parameters
[ ] Date displayed as numerical month and day with day of week displayed in letters
[ ] 24 hour time of day
[ ] 1 minute resolution for programming On-Off times
[ ] 12 holiday programming for On or Off events for each circuit
[ ] Four On and four Off events programming capacity for each circuit
[ ] Automatic Standard and Daylight savings time adjustment
[ ] 4 day battery backup
[ ] Power consumption less than 10 watts
[ ] [ ] Location correct

[ ] [ ] Labeled correctly
[ ] [ ] Rail mounted

10. HIGH SIGNAL SELECT
[ ] [ ] Location correct
[ ] [ ] Labeled correctly
[ ] [ ] Rail mounted
[ ] Accuracy - plus or minus 1% of input span
[ ] Power consumption less than 5 watts
[ ] Uses mAdc input and output
[ ] 120 Vac powered

11. MINIMUM POSITION SWITCH
[ ] [ ] Location correct
[ ] [ ] Labeled correctly
[ ] [ ] Rail mounted
[ ] mAdc output
[ ] Input isolated from output
[ ] 8-pin socket

12. AC OUTLET
[ ] [ ] Correctly located

13. RELAYS
[ ] 2-pole, double-throw
[ ] 10 amp rating at 120 Vac
[ ] Enclosed 120 Vac coil
[ ] 8 pin connectors
[ ] Matching socket
[ ] Power consumption not greater than 3 watts
[ ] [ ] Sockets mounted on specified rails

14. PANEL POWER WIRING
[ ] [ ] 120 Vac terminated at terminal strip
[ ] [ ] Instrument cases grounded
[ ] [ ] Interior plate grounded
[ ] [ ] Interior door grounded
[ ] [ ] Exterior door grounded
[ ] [ ] 16 AWG minimum with 600 volt rating

15. PANEL LOW VOLTAGE WIRING
[ ] Minimum 14 AWG, 300 volt rating for 24 Vdc circuit wiring
[ ] Minimum 20 AWG, 300 volt rating for analog signal circuit wiring located within panel
[ ] No splices
[ ] No more than two wires connected to a terminal
[ ] Controller wiring identified by function and polarity
[ ] EMCS terminal jumpered or connected

16. PANEL WIRING DUCTS

[ ] [ ] Location correct
[ ] [ ] Nonconducting
[ ] [ ] Slotted sides
[ ] [ ] Snap-on duct covers
[ ] [ ] Affixed to back plate
[ ] [ ] Horizontal duct size 1.5 in. x 3 in.
[ ] [ ] Verticle duct size 2 in. x 3 in.

17. INSTRUMENTATION CABLES

[ ] 18 AWG wire
[ ] Twisted, stranded copper wire
[ ] Minimum 2-inch lay of twist
[ ] 100% shielded pairs
[ ] 300 volt insulation
[ ] 20 AWG tinned-copper drain wire per pair
[ ] Overall pair insulation
[ ] Overall aluminum-polyester or tinned-copper cable-shield tape for each cable

18. TERMINAL BLOCKS

[ ] [ ] Correct location
[ ] [ ] Insulated
[ ] [ ] Modular
[ ] [ ] Feed-through
[ ] [ ] Clamp style
[ ] [ ] Recessed captive screw-type clamping mechanisms
[ ] [ ] Rail mounted
[ ] [ ] End plates
[ ] [ ] Partition plates
[ ] Common instrument signal grounds connected to common point
[ ] Common shield grounds connected to common point
[ ] Grounding points identified by reference level

19. PLASTIC PNEUMATIC TUBING

[ ] [ ] Barbed fittings and valves
[ ] Burning characteristics of linear low-density polyethylene tubing
[ ] Self-extinguishing per ASTM Spec. D 635
[ ] UL 94 V-2 flammability classification
[ ] Withstand stress cracking per ASTM Spec. D 1693
[ ] [ ] Main air shutoff valve piped correctly
[ ] [ ] 1/4 in. tubing used

20. COPPER PNEUMATIC TUBING

[ ] Conform to ASTM Spec. 88

[ ] Sweat fittings and valves

21. STAINLESS STEEL TUBING

[ ] Conform to ASTM Spec. A 269

[ ] Compression fitting

22. PNEUMATIC CONNECTION TO PANEL

[ ] [ ] Bulkhead fittings at bottom of panel

[ ] [ ] Manual valve for shutoff of main air

8 COMMISSIONING OF CONTROL SYSTEMS

GENERAL

This section deals with the commissioning of standard HVAC control systems. The purpose of this section is to describe the commissioning process for the standard control systems, discuss roles of personnel that are involved in the commissioning process, and discuss documentation. Commissioning Procedures and Report for a Multizone HVAC Control System are included at the end of this section. These procedures contain the level of detail that would be ideal for use in commissioning the system. They are provided as an example of what is desirable as a submittal from the contractor.

OVERVIEW OF COMMISSIONING

Commissioning is the process of setting up, calibrating, adjusting, and tuning a control system so that it performs according to the design and specifications. Following is an overview of the activities that are to be performed during the commissioning of standard HVAC control systems. Depending on the specific system, some activities may not be required.

1. Commissioning personnel should set up the HVAC system so that the commissioning of the system can begin. Before power is supplied to the panel and other HVAC system devices, the Hand-Off-Auto (HOA) switches for the fans, pumps, and any other motor-driven devices connected to the control system should be placed in the OFF position. This is done to ensure that a sufficient level of control is available when the HVAC system is first started to prevent possible damage to HVAC equipment. For example, starting the fans of a VAV system before the controllers have been set up and tuned could result in unstable control, resulting in the fans overpressurizing and possibly damaging the air ducts.

2. Commissioning personnel must confirm that main air is supplied to the panel. For all standard control systems that use pneumatic actuation, commissioning personnel should confirm that the main air supplied to the panel is at least 20 psig. This is needed to ensure that the control air pressure to the pilot/positive positioners, located on pneumatically actuated devices, can reach 15 psig.

3. Commissioning personnel must confirm that field devices are correctly located and installed to ensure that the control system will perform correctly. Temperature sensors, temperature alarm sensors, smoke detectors, and other control system devices must be checked for proper location and installation. The best way to check proper location is to refer to the Control System Schematic drawing for the particular system and code requirements. The best way to check proper installation is to refer to the manufacturer's data sheets for the various devices. One specific device to watch for are averaging temperature sensors. These sensors should be serpentined across the duct section so that a true average is attained.

4. Commissioning personnel must confirm that the normal positions of the various devices are correct. Dampers and valves should go to their normally closed, or open, positions when the system is shut down, when power is off, when main air is off, or in any other situations where

the control signal to a particular device is at its minimum value. The best way to confirm a device's proper normal position is to refer to the Control System Schematic drawing. The drawing will note whether a device is normally open (NO) or normally closed (NC). Outside air dampers, relief air dampers, cooling coil valves, and fan inlet guide vanes are usually NC and return air dampers and heating coil valves are usually NO.

5. Commissioning personnel must set up and configure the controllers so that they will control their loops and interface with other devices correctly. Some panels may be delivered with the controllers already set up and configured so that the commissioning personnel will not have to do this. Most controllers have dip switches and internal jumpers that must be set during the commissioning process. A Controller Configuration Checksheet showing all dip switch positions, jumpers, and configuration parameters must be provided for each controller when the contractor submits the Commissioning Procedures. The Configuration Checksheets should show recommended initial P-, I-, and D-mode values. The user manuals for each controller will give detailed information on how to scroll through the controller's menus to set up the configuration parameters and will show locations of dip switches and jumpers.

   In the earlier lab session, instructions were given on how to set up and configure a controller for both Economizer and Setpoint Reset. The procedure for setting up and configuring controllers for other applications is the same except that some of the parameters and dip switch and jumper positions change.

6. Early in the commissioning process, commissioning personnel should set up and configure time clocks so that they will have the correct operating schedule. The operating schedule of the system is found on the Equipment Schedule drawing. It is recommended that the Contractor be requested to supply a Time Clock Configuration Checksheet. This should be checked to assure that the correct holiday schedule has been entered and that the daylight savings time feature has been activated, if required. Some time clocks have dip switches and jumpers to set. These should also be noted on any reports. The Time Clock User Manual will give specific details on how to scroll through the time clock settings and will show locations of dip switches and jumpers.

7. Commissioning personnel should perform Asensor-to-controller-readout@ calibration accuracy checks to confirm that a controller is displaying the correct temperature, static pressure, or volumetric air flow. CEGS 15950 requires a two-point calibration accuracy check of all HVAC control system sensor/transmitter assemblies. The procedure is to measure the temperature, or other process variable, and compare the measured value to the value displayed by the controller. Digital indicating test instruments, such as digital thermometers, must be used. The test instruments must be at least twice as accurate as the specified sensor-to-controller readout accuracy.

   The accuracy checks must be performed at two different process variable values. For example, a mixed air temperature sensor has a range of 40 to 140E F. It should be checked in the 45 to 55E F range and in the 80 to 90E F range.

   For averaging-temperature sensor-to-controller-readout accuracy checks (i.e., mixed air, cold deck and hot deck temperatures), measurement of the temperature shall be checked every 2 feet along the axis of the sensor in the proximity of the sensor. A maximum of 10 readings shall be averaged.

Generally, configuration of the controllers in previous steps should have set up the controller to perform properly, thus no adjustments should be required. Transmitters are factory set for the appropriate range and should require no adjustments either. Sensing devices, such as Resistance Temperature Detectors (RTDs), are manufactured to give a standard response to different process variable values and require no adjustment.

Controller and transmitter ranges and sensing device responses can be found in the Operation and Maintenance Instruction Booklets, Equipment Data Booklet, and in the Equipment Schedule sections of the Shop Drawings.

8. Commissioning personnel should calibrate and adjust devices so that loops are controlled correctly. For example, a controller providing an output to an I/P transducer should be adjusted to produce a 0 percent output (4 mA) and then it should be confirmed that the I/P outputs 3 psig. The pilot/positive positioner should then be adjusted so that the controlled device moves to its normal position. Next, the controller's output should be adjusted to 100 percent (20 mA) to confirm that the I/P outputs 15 psig. The positive positioner should then be adjusted so that the device being controlled moves to its fully open or fully closed position. If electric actuators are used, commissioning personnel should confirm that the devices move to their normal positions when the controller's output is 0.0 percent and move to their fully open or closed position when the controller's output is 100 percent.

   The controllers are factory-calibrated to output a 4-20 mA signal for a 0 to 100 percent controller output range and should require no adjustments. The previously performed Controller Setup and Configuration Step should have set up the correct output ranges for the controllers. The I/P transducers are factory set to give a 3-15 psig output for a corresponding 4-20 mA input and should require no adjustments. The damper actuators are factory-calibrated for their specific spring ranges and should require no adjustments. The pilot positioners are not set up for the appropriate ranges so adjustments are required. Electric actuators are factory-calibrated for 4-20 mA ranges and should require no adjustments. Specific information on how to set up the positive/pilot positioners will be found in the manufacturer's data sheets.

9. Commissioning personnel should place the control system in the Ventilation-Delay mode, and confirm that the HVAC system operates correctly. Hydronic-type systems do not utilize the delayed ventilation mode, but for all air-type standard control systems, when the system is in the Ventilation-Delay mode, the commissioning personnel should confirm that outside air dampers and relief air dampers are completely closed and return air dampers are fully open. In addition, for some standard control systems, it should be confirmed that cooling coil valves and heating coil valves can be modulated, that DX condensing units will operate, and that humidifier valves can be modulated.

10. Commissioning personnel should place the control system in the Occupied mode, and confirm that the control system operates correctly. Both air-type and hydronic HVAC systems have this mode of operation, but only air damper operation needs to be checked at this point since the operation of valves and pumps is confirmed in other sections of the commissioning process. When the system is in the Occupied mode, commissioning personnel should confirm that outside, relief, and return air dampers can be modulated.

11. Commissioning personnel should place the control system in the Unoccupied/shutdown mode, and confirm that the control system operates correctly. For all standard control systems, when the system is in the Unoccupied mode, the commissioning personnel must confirm that outside air dampers and relief air dampers are completely closed and return air dampers are fully open. For some standard control systems, it should be confirmed that cooling coil valves are closed, that heating coil valves can be modulated, that DX units will not turn on, and that the humidifier valves are closed.

12. Commissioning personnel should confirm that the Economizer controller operates correctly. For all air-type standard control systems, Economizer controllers are not tuned. The Economizer controller does not provide a variable output signal to a device. Rather, it opens and closes the deviation and process variable contacts based on temperature settings. Commissioning personnel must confirm that the deviation and process contacts open and close at the specified settings.

13. Commissioning personnel must adjust the minimum position switch so that the correct amount of outside air is introduced into the system when the Economizer is OFF. Coordination with Air Balancing personnel may be required for this step.

    For all air-type standard control systems, when the system is in the Occupied/Ventilation-Delay mode, and the Economizer controller is OFF, the Minimum Position Switch must be adjusted until the correct amount of outside air is introduced. This must be performed when the outside air temperature is at least 10E F higher or lower than the return air temperature so that an accurate check can be performed. The percent of outside air can be determined by the following equation:

$$\text{PERCENT OA} = 100*(\text{MAT} - \text{RAT})/(\text{OAT} - \text{RAT})$$

14. Commissioning personnel must confirm that the Outside Air Temperature (OAT) controller resets the setpoints of the other controllers correctly and cycles pumps correctly, based on the OAT. The commissioning personnel should simulate three different OATs and verify that for the OAT shown on the OAT controller, the temperature controller setpoint varies according to the reset schedule shown on the System Schematic. OATs near the high end, low end, and middle range of the reset schedule should be simulated.

    The commissioning personnel must confirm that the high limit setpoint is not exceeded for the reset schedule by decreasing the simulated OAT below the high-limit setpoint's corresponding OAT value and confirming that the temperature controller's setpoint does not increase above the high-limit setpoint.

For Hydronic systems, with the pumps running, the OAT should be increased until its value is above the process variable contact's setpoint plus the hysteresis to confirm that the pumps stop. Then, the OAT should be decreased to confirm that the pumps do not start until the OAT is below the process variable contact's setpoint.

15. Commissioning personnel must tune controllers so that they correctly control a loop. A controller should be tuned when its respective process is in its high gain condition. A high gain condition occurs when a given process is lightly loaded. For example, the high gain condition for a heating coil loop is generally when it is warm outside and very little heating is required. Under this condition, the heating coil valve will be only partially open and small changes in the valve position will result in large changes in flow through the valve. The output of the heating coil responds very rapidly to small movements of the hot water control valve. If high gain conditions do not exist at the design setpoint, the controller can be tuned at a setpoint that does result in a high gain position and the setpoint later returned to the design setpoint. If the system can correctly control the process under high gain conditions, it will be able to control the process under other conditions as well. If the process is tuned under low gain conditions, it is possible that the system will be unstable under high gain conditions.

    The auto tuning (self-tuning) feature shall be used to tune controllers unless auto tuning does not provide appropriate control. Self-tuning of controllers usually is done by pressing the self-tuning button on the controller.

    Controller manual-tuning procedure: The controller manual-tuning procedure is hereinafter described in three steps using a constant-temperature setpoint controller as an example.

    Step A:

    a. Index the controller's MANUAL/AUTO station to the AUTO position and set the derivative-mode constant to zero. If the integral mode constant is expressed in units of repeats/minute, then set it to zero. If the integral mode constant is expressed in units of minutes/repeat, then set it to its maximum possible value.
    b. Set the proportional-mode constant to an initial setting of 8 percent. (This corresponds to a 1.5 psig per EF or a 2.0 mA per EF proportional output change for a 100E F transmitter span). This causes the controller's output signal to vary from zero output to full output for an input signal change representing an 8E F change.
    c. Controllers for other variables, such as relative humidity and static pressure, shall have their proportional-mode constants set initially in a similar manner for an achievable output range proportional to the transmitter span.

    Step B:

    a. Set the controller's temperature setpoint at an achievable value which is also a high gain condition. Observe the controller's output and transmitter input.
    b. If the transmitter's input continuously oscillates above and below the setpoint without settling at a fixed value, or if such oscillation increases, the proportional-mode constant is too small.

c. If the proportional-mode constant is too small, increase it in steps until the transmitter's input indicates stable control at any temperature, provided that the controller's output is not at either extreme of its range.

d. If the temperature control point slowly drifts toward or away from the controller setpoint, the proportional-mode constant is too large. Decrease its setting in steps until oscillations occur as described in the preceding paragraphs, and then increase the setting until stable control occurs.

e. Introduce a step change in controller setpoint. This should cause the controller to overshoot the setpoint slightly, with each subsequent overshoot peak value decreasing by a factor of 2/3 until stable control is achieved at, above, or below the setpoint.

f. Next, increase the integral-mode constant setting in small steps, and introduce setpoint changes until control point and controller setpoint coincide at stable control. This should happen consistently after a setpoint change within a short time, such as 5 to 10 minutes.

Step C:

a. Unless a given process variable changes rapidly, the derivative-mode constant setting can remain at zero.

b. If derivative control is needed, gradually increase the derivative-mode constant.

c. Introduce step changes in controller setpoint, and adjust the derivative-mode constant setting until stable control is achieved.

16. Commissioning personnel must confirm that the cooling coil controller's remote setpoint can be reset. The commissioning personnel should first place the controller in the remote setpoint (RSP) mode, then apply a 12 mA signal to the RSP (CPA) terminals of the controller and confirm that the controller setpoint is equal to the local setpoint (LSP). Next, a 4 mA signal should be applied to the RSP (CPA) terminals of the controller to confirm that the controller setpoint is 5 less than the LSP. A 20 mA signal should be applied to the RSP (CPA) terminals of the controller to confirm that the controller setpoint is 5 more than the RSP.

17. Commissioning personnel should confirm that the Space Temperature controller's remote setpoint can be reset. Personnel should first place the controller in the RSP mode, then apply a 12 mA signal to the RSP (CPA) terminals of the controller and confirm that the space temperature controller setpoint is 70. Next, a 4 mA signal should be applied to the RSP (CPA) terminals of the controller to confirm that the Space Temperature controller's setpoint is 55. Then, a 20 mA signal should be applied to the RSP (CPA) terminals of the controller to confirm that the Space Temperature controller's setpoint is 85.

18. Commissioning personnel should set the night thermostat setpoint and confirm that the control system operates correctly under night stat alarm conditions. Personnel should place the system in the unoccupied mode so that the system shuts down. The night thermostat should be actuated by adjusting the setpoint upward to confirm that the fans, or pumps, start. It should be confirmed that cooling coil valves remain closed, that heating coil valves can be modulated, that outside air dampers remain in their normally closed positions, and that return air dampers remain in their normally open position. Also, it should be confirmed that humidifier valves

remain closed and that heat exchanger valves can be modulated. The night stat setpoint should be turned downward to verify that the fans, or pumps, shut down.

After completing the check, the night thermostat setpoint should be set to the specified setting and the setpoint should be recorded in the Commissioning Report and on the Equipment Schedule.

19. Commissioning personnel should simulate a Smoke Alarm and confirm that the control system operates correctly under smoke alarm conditions. Only air-type HVAC systems are shut down by smoke alarm activation in standard control systems; hydronic-type systems are not. The HVAC systems will operate with the fan motor's HOA switches in AUTO or HAND position, so the system operation must be checked with the HOA switches in both positions.

    With the fans running, the commissioning personnel should simulate a Smoke Alarm without false-alarming any life safety systems and causing a false fire alarm. They should then confirm that the fans shut down and the SMOKE pilot light turns on. The smoke alarm should be reset and it should be confirmed that the SMOKE pilot light turns off, but that the fans will not restart. Then, the panel's RESET button should be depressed to observe that the fans will then start.

20. Commissioning personnel should set the low-temperature thermostat's setpoint to confirm that the control system operates correctly under low-temperature alarm conditions. Only air-type HVAC systems are shut down by low air temperature alarm activation in standard control systems; hydronic systems are not. The HVAC systems will operate with the fan motor's HOA switch in its AUTO or HAND position, so the system operation must be checked with the HOA switches in both positions.

    With the fans running, a low-temperature alarm should be simulated by increasing the thermostat's trip setpoint above the mixed air temperature. It should be confirmed that the fans shut down and that the LOW TEMPERATURE pilot light illuminates. The low temperature thermostat's setpoint should be reset below the mixed air temperature and the thermostat's reset switch should be pressed. Then it should be observed that the LOW TEMPERATURE pilot light turns off, but the fans remain shut down. Pressing the panel's RESET button should confirm that the fans will then start.

21. Commissioning personnel must set the filter differential pressure switch setpoint and confirm that the system operates correctly under a Filter Alarm condition. With the fans running, personnel should simulate a Filter Alarm at the differential pressure switch. They should then confirm that the FILTER pilot light illuminates. Then, they should reset the filter differential pressure switch and verify that the FILTER light turns off.

22. Commissioning personnel should simulate a high static pressure alarm and confirm that the fans shut down. Only VAV-type HVAC systems are shut down by high static alarm activation. The HVAC systems should operate with the fan motors' HOA switches in their AUTO or HAND positions, so the system operation should be checked with the HOA switches in both positions. With the fans running, a High Static Alarm should be simulated. It should be confirmed that the fans shut down and the HIGH STATIC pilot light turns on. Then, the

high static alarm should be reset and it should be noted that the HIGH STATIC pilot light turns off, but the fans will not restart. The panel's RESET button should be pressed to observe that the fans will then start.

23. Commissioning personnel must confirm that the control panel's ENABLE/OFF switches will shut down all or parts of the HVAC system as designed.

    Refer to TM Figures 4-7B, 4-10B, and 4-14B for the three different standard control applications of ENABLE/OFF switches.

    The time clock should be reset so that the system is in the Occupied mode, the HOA switch place in the AUTO position, and the system placed in the HEATING mode, or in the PUMP ON mode if necessary, so that the fans, or pumps, are running. Then, the ENABLE/OFF switch should be pressed so that the OFF light illuminates. It should be confirmed that the fans, or pumps, shut down. The ENABLE/OFF switch should be pressed again to verify that the ENABLE light illuminates, and the fans or pumps start.

24. Commissioning personnel must confirm that the control panel's AUTO/OVERRIDE switch will start the HVAC system as designed.

    Refer to TM Figures 4-7B, 4-10B, and 4-14B for the three different standard control applications of AUTO/OVERRIDE switches.

    The time clock should be reset so that the system is in the Unoccupied mode, the HOA switch should be placed in the AUTO position. Then, the controller setpoints should be changed or, if necessary, the heating/cooling switches should be changed so that the fans or pumps are shut down. Then the AUTO/OVERRIDE switch should be pressed to verify that the OVERRIDE light illuminates, the fans, or pumps, turn on and the OCCUPIED light illuminates. Then, AUTO/OVERRIDE switch should be indexed so that the AUTO pilot light illuminates. Finally, it should be confirmed that the fans or pumps stop.

25. Commissioning personnel must set up zone control units. For Multizone and Dual-Duct systems, personnel must set each zone thermostat's setpoint and, if programmable thermostats are used, schedules must be set.

    For VAV systems, personnel should set the VAV terminal boxes' minimum and maximum flow rates, and room temperature setpoints. This may have to be coordinated with the Air Balance team.

26. Commissioning personnel must check the calibration of zone control sensing devices. The commissioning personnel should confirm that the measured temperature at each thermostat location is within 1E F of the displayed room thermostat temperature.

27. Commissioning personnel must check the operation of zone control units. For Multizone and Dual-Duct systems, personnel should adjust devices so that when the thermostat setpoint is equal to the actual room temperature plus one-half of the thermostat's throttling range, the zone's hot deck dampers move to the wide open position and the zone's cold deck dampers

move to the fully closed position. Then, personnel should adjust devices so that when the thermostat setpoint is equal to the actual room temperature minus one-half of the thermostat's throttling range, the zone's hot deck dampers move to the fully closed position and the zone's cold deck damper moves to the wide open position.

28. Commissioning personnel must note values and system reactions on the Commissioning Report. Personnel must permanently record, on the system's Equipment Schedule, for each controller, the final proportional, integral, and derivative constants, the setpoints, and the maximum and minimum outputs, in units and terminology specific to each controller.

Weather-dependent procedures that cannot be performed by simulation shall be performed in the appropriate season. When simulation is used, the Contractor shall verify the actual results in the appropriate season.

At the conclusion of the commissioning process, the HVAC control system should be controlling the system correctly and accurately. If the commissioning is done incorrectly, it could cause the Performance Verification Tests to take longer to conduct. Also, the HVAC system may consume more energy than designed, may cause uncomfortable space conditions, and may be a burden to the maintenance crew.

COMMISSIONING PROCESS RESPONSIBILITIES

The whole commissioning Aprocess@ does not simply begin after the system has been installed. Rather, it begins at the predesign phase and evolves as the project proceeds from one phase to another, culminating in the acceptance of the system. At each phase, details of how the system will be placed into operation are added until all the information about how the system operates and performs are included in Commissioning Procedures and Reports.

The predesign phase of the development of Commissioning Procedures has already been done, to a large extent. Specifications on the content of the Commissioning Procedures and Commissioning Report are included in Section 1.4 of CEGS 15950.

The designer must indicate in the specifications how many copies of the Commissioning Procedures should be submitted by the contractor. If the project has a building with several HVAC control systems that are identical, providing six copies of the Commissioning Procedures for each system is probably not desirable. This would unnecessarily increase the cost of documentation, and may cause a storage problem for Construction personnel and the DPW. Only one set of Commissioning Procedures for each identical type of control system would be sufficient, but a Commissioning Report should be done for each system.

The designer should include the Commissioning Procedures for each control system as written in Section 3.4 of CEGS 15950 in the contract package. Should the control system change from the standard designs, the designer should have modified the Commissioning Procedures as needed.

The contractor is responsible for submitting finalized versions of the Commissioning Procedures and submitting them not later than 60 days prior to the start of commissioning. The contractor is responsible also to perform the Commissioning Procedures, and to fill out and submit the Commissioning Report.

The Corps QV personnel are responsible for approving the Commissioning Procedures and notifying the contractor that he/she may proceed with commissioning of the system. They are responsible also for approving the Commissioning Report and notifying the contractor that he/she may proceed with the Performance Verification Test (PVT). QV personnel are not required to be present at the commissioning, since actual acceptance of the system is done during the PVT, described on page 111.

SYNOPSIS OF CEGS-15950 ON COMMISSIONING

The Guide Specification requires that the Contractor submit Commissioning Procedures for each HVAC control system and each type of terminal-unit control system before the system is commissioned. Terminal units are items such as VAV box controls and multizone thermostats. If a system has different types of VAV boxes, such as a cooling-only box and a cooling-with-reheat box, and the control units are different, then the Contractor should submit commissioning procedures for each type.

The Commissioning Procedures, as written in Section 3.4 of CEGS-15950, are generic commissioning procedures that the Contractor is supposed to follow. The Commissioning Procedures submitted by the Contractor should reflect the language and format of the specifications, but should be expanded to include details concerning configuration of controllers, adjusting of pilot positioners, transmitters, etc.

Many of the devices used in the standard control systems are factory calibrated and should not require any calibration in the field. Details on how to calibrate and adjust these items need not be included in the Commissioning Procedures, but they should be included in either the Operation and Maintenance Booklet or the Equipment Data Booklet. The Commissioning Procedures should then direct commissioning personnel to refer to the Booklets for adjustment procedures should these devices need adjustments.

The Commissioning Report should show the values and results of adjustments, calibration, setup, and configuration of all components of the control system. CEGS 15950 does not specify the number of days after commissioning within which the Commissioning Report should be submitted. The designer may want to specify when the Report should be submitted.

The Commissioning Procedures have several uses; they instruct the commissioning personnel how to correctly commission the system, let QV personnel know whether the commissioning is being done correctly, and provide operation and maintenance personnel with information that is valuable for troubleshooting, evaluating, and recommissioning of the system.

The Commissioning Report lets QV personnel know whether the commissioning has been done correctly and provides operation and maintenance personnel with information that is valuable for troubleshooting, evaluating, and recommissioning of the system.

Although QV personnel will usually be responsible for approving the Commissioning Procedures and Report, the designer should review them also. Government personnel are not required to be present during commissioning since actual acceptance of the system will occur during the PVT. By reviewing the Commissioning Procedures and Report, QV personnel should be able to determine whether the system has been commissioned correctly before proceeding to the PVT, and should then be able to conduct the PVT without any problems.

EXPANDED COMMISSIONING PROCEDURES FOR MULTIZONE SYSTEMS

GENERAL INFORMATION

1. Personnel performing the commissioning of the systems should refer to the Operation and Maintenance Instructions and Equipment Data Booklet for specific information dealing with calibration, configuring, tuning, and adjusting of specific devices and components.

2. Commissioning personnel shall tune controllers, conduct observations, make adjustments, perform calibrations, take measurements, and do tests of the control systems, making any necessary control system corrections to ensure that the systems functions as described in the Sequence of Operation.

3. Commissioning personnel shall note values and system reaction on the Commissioning Report. Personnel shall permanently record, on the system Equipment Schedule, for each controller, the final proportional, integral, and derivative constants, the setpoints, and the maximum and minimum outputs, in units and terminology specific to each controller.

4. Signals used to change the mode of operation shall originate from the actual HVAC control device intended for the purpose. External input signals from the EMCS to the HVAC control panel may be simulated.

5. Weather-dependent procedures that cannot be performed by simulation shall be performed in the appropriate season. When simulation is used, the Contractor shall verify the actual results in the appropriate season.

Note: The designer and\or contractor should choose the appropriate response for words placed in brackets [ ] [ ] to complete the commissioning procedures.

OFF/SHUTDOWN CONDITION COMMISSIONING

The Off/Shutdown Condition Commissioning is done to ensure that a sufficient level of control is available when the HVAC system is first started to prevent possible damage to HVAC equipment.

1. SYSTEM INSPECTION

   a. Place the Hand-Off-Auto (HOA) switches for the Supply Fan (SF-XX01) and Return Fan (RF-XX01) in the off position.

b. Apply power to the control panel by placing switch (xxxx) in the on position. [Apply compressed air to the panel by placing the main air valve (xxxx) in the (xxxx) position.] Check to see that power is available at the HVAC system control panel. [Check to see that air is available at the HVAC system control panel. The Control Panel's Main Air Gage should read between 20 and 25 psi.]

c. Refer to the Multizone Control System Schematic drawing, check to see that all temperature sensors, temperature alarm sensors, and smoke alarm sensors have been properly located and installed.

d. Check to see that the Outside-Air Dampers (AD-xx01), Relief-Air Dampers (AD-xx03), and Cooling-Coil Valve (VLV-xx01) are in their normally closed positions, and the Return-Air Dampers (AD-xx02) and Heating Coil Valve (VLV-xx02) are open.

2. SETUP AND CONFIGURATION OF CONTROLLERS

a. General: The controllers that must be configured are: Economizer (EC-xx01), Mixed Air Temperature (TC-xx01), Cold Deck Temperature (TC-xx02), Hot Deck Temperature (TC-xx03), and Outside Air Temperature (TC-xx04).

b. Delivered State: All controllers mounted in the panel are delivered/installed [with] [without] the Dip Switches and configuration parameters being set, and the internal jumpers in place.

c. Responsibilities: The commissioning personnel [are] [are not] responsible for setting the controllers' Dip Switches, Configuration Parameters, and Internal Jumpers.

d. Adjustment Procedures: Refer to the User Manuals for each controller, located in the Operation and Maintenance Instruction Booklet, for scrolling through the controller settings, and locations of Dip Switches and jumpers.

e. Settings: Dip Switch settings, Configuration Parameters, Internal Jumper settings and initial PID values for each controller are listed on each Controller Configuration Checksheet, located in the Operation and Maintenance Instruction Booklet.

3. SETUP AND CONFIGURATION OF TIME CLOCK

a. General: The Time Clock (CLK-xx01) is the only component to be setup in this step.

b. Delivered State: The Time Clock is delivered/installed [with] [without] the Dip Switches and configuration parameters being set, [and] [or] the internal jumpers in place.

c. Responsibilities: It [is] [is not] the commissioning personnel's responsibility to set Dip Switches, Configuration Parameters, and Internal Jumpers.

d. Adjustment Procedures: Refer to the Time Clock User Manual, located in the Operation and Maintenance Instruction Booklet, for scrolling through the Time Clock setting and locations of Dip Switches and jumpers.

e. Settings: Dip Switch settings, Configuration Parameters, and Internal Jumper settings are listed on the Time Clock Configuration Checksheet, located in the Operation and Maintenance Instruction Booklet. The HVAC system operation schedule is listed on the Equipment Schedule.

4. ADJUSTMENTS AND CALIBRATION CHECKS OF CONTROLLED DEVICES

a. General: The circuits which will be checked are the Mixed Air Dampers, the Cold Deck Valve, and the Hot Deck Valve.

b. Delivered State: The controllers (TC-xx01), (TC-xx02) and (TC-xx03) are factory calibrated to output a 4-20 mA signal for a 0 to 100 percent controller output range, and should require no adjustments. The previously performed Controller Setup and Configuration Step (Section 1.2) should have set up the correct output ranges for the controllers. [The I/P transducers (IP-xx01), (IP-xx02) and (IP-xx03) are factory set to give a 3-15 psi output for a corresponding 4-20 mA input and should require no adjustments. The damper actuators are factory calibrated for [8-13] [ ] psi ranges and should require no adjustments. The pilot positioners are not set up for the appropriate ranges so adjustments are required.] [The damper actuators are factory calibrated for 4-20 mA ranges and should require no adjustments.]

c. Responsibilities. It is the commissioning personnel's responsibility to confirm that the circuit performs correctly, [set up the pilot positioners so that they operate over the correct ranges,] make any necessary adjustments, and replace any faulty components. Should problems occur, commissioning personnel should refer to the Operation and Maintenance Instruction Booklets for diagnostic, adjustment, and repair procedures.

(1) Mixed Air Damper Circuit

General: The components that must be checked or adjusted are: the output of the MAT controller (TC-xx01), [(IP-xx01),] the outside air damper (AD-xx01), the outside air damper actuator [and pilot positioner] (DA-xx01), the return air damper (AD-xx02), the return air damper actuator [and pilot positioner] (DA-xx02), the relief air damper (AD-xx03), and the relief air damper actuator [and pilot positioner] (DA-xx03).

Calibration Check, Settings and Adjustment Procedures for the MAT control circuit: Bypass relay contacts R-xx07 and R-xx03, and the High Signal Select module (TY-xx01) by placing a jumper from [the positive output terminal of TC-xx01 to the positive terminal of IP-xx01][pin 19 on the panel terminal block to the actuator side of relay contact R-xx03]. Place the MAT controller (TC-xx01) in the manual mode and adjust the controller output to zero percent (4 mA). [The MAT Pressure Gage (PI-xx01) should read 3 psi. Adjust IP-xx01 if necessary. Adjust the Zero Screw on the pilot positioner of the Outside Air Damper Actuator (DA-xx01) so that the Outside Air Dampers (AD-xx03) are fully closed. Adjust the Zero Screw on the pilot positioner of the Relief Air Damper Actuator (DA-xx03) so that the Relief Air Dampers (AD-xx03) are fully closed. Adjust the Zero Screw on the pilot positioner of the Return Air Damper Actuator (DA-xx02) so that the Return Air Dampers (AD-xx02) are fully open.] [Confirm that the Outside Air Damper Actuator (DA-xx01) moves the Outside Air Dampers (AD-xx03) to the fully closed position. Confirm that the Relief Air Damper Actuator (DA-xx03) moves the Relief Air Dampers (AD-xx03) to the fully closed position. Confirm that the Return Air Damper Actuator (DA-xx02) moves the Return Air Dampers (AD-xx02) to the fully open position.] Adjust the MAT controller output to 100 percent (20 mA). [The MAT Pressure Gage should read 15 psi. Adjust IP-xx01 if necessary. Adjust the Span Spring on the pilot positioner of the Outside Air Damper Actuator (DA-xx01) so that the Outside Air Dampers (AD-xx03) are fully open. Adjust the Span Spring on the pilot positioner of the Relief Air Damper Actuator (DA-xx03) so that the Relief Air Dampers (AD-xx03) are fully open. Adjust the Span Spring on the pilot positioner of the Return Air Damper Actuator (DA-xx02) so that the Return Air Dampers (AD-xx02) are fully closed. Repeat the low and high signals and check for correct action of the dampers.] [Confirm that the Outside Air Damper Actuator (DA-xx01) moves the Outside Air Dampers (AD-xx03) to the fully open position. Confirm that the Relief Air Damper Actuator (DA-xx03) moves the Relief Air Dampers (AD-xx03) to the fully open position. Confirm that the Return Air Damper Actuator (DA-xx02) moves the Return Air Dampers (AD-xx02) to the fully closed position.] Remove the jumper and place the MAT controller in the auto mode.

(2) Cold Deck (Cooling Coil) Valve Circuit

General: The components which must be checked or adjusted are: the output of the Cold Deck Temperature (CDT) controller (TC-xx02), [IP-xx02,] and the cooling coil valve, actuator [and pilot positioner] (VLV-xx01).

Calibration Check, Settings and Adjustment Procedures for the CDT control loop: Bypass the R-xx06 relay contact by placing a jumper from [the positive output terminal of TC-xx02 to the positive terminal of IP-xx02.][pin 29 on the panel terminal block to the actuator side of relay contact R-xx06.] Place the CDT controller (TC-xx02) in the manual mode and adjust the controller output to zero percent (4 mA). [The CDT Pressure Gage (PI-xx02) should read 3 psi. Adjust IP-xx02 if necessary. Adjust the Zero Screw on the pilot positioner of the Cooling Coil Valve Actuator so that the Cooling Coil Valve (VLV-xx01) is fully closed.] [Confirm that the Cooling Coil Valve Actuator moves the Cooling Coil Valve (VLV-xx01) to the fully closed position.] Adjust the controller output to 100 percent (20 mA). [The CDT Pressure Gage should read 15 psi. Adjust IP-xx02 if necessary. Adjust the Span Spring on the pilot positioner of the cooling coil valve actuator so that the Cooling Coil Valve (VLV-xx01) is fully open. Repeat the low and high signals and check for correct action of the valve.] [Confirm that the Cooling Coil Valve Actuator moves the Cooling Coil Valve to the fully open position. Remove the jumper and return the controller to the automatic mode.]

(3) Hot Deck (Heating Coil) Valve Circuit

General: The components that must be checked or adjusted are: the output of the Hot Deck Temperature (HDT) controller (TC-xx03), [IP-xx03,] the heating coil valve, actuator [and pilot positioner] (VLV-xx02).

Calibration Check, Settings and Adjustment Procedures for the HDT control loop: Place the HDT controller (TC-xx03) in the manual mode and adjust the controller output to zero percent (4 mA). [The HDT Pressure Gage (PI-xx03) should read 3 psi. Adjust IP-xx03 if necessary. Adjust the Zero Screw on the pilot positioner of the Heating Coil Valve Actuator so that the Heating Coil Valve (VLV-xx02) is fully open.] [Confirm that the Heating Coil Valve Actuator moves the Heating Coil Valve (VLV-xx02) to the fully closed position.] Adjust the controller output to 100 percent (20 mA). [The HDT Pressure Gage should read 15 psi. Adjust IP-xx03 if necessary. Adjust the Span Spring on the pilot positioner of the heating coil valve actuator so that the Heating Coil Valve (VLV-xx02) is fully closed. Repeat the low and high signals and check for correct action of the valve.] [Confirm that the Heating Coil Valve Actuator moves the Heating Coil Valve to the fully closed position.]

AUTOMATIC OPERATING CONDITION COMMISSIONING

1. SCHEDULED OPERATING MODES

a. General: The next three sections check the operation of the Mixed Air Dampers, the cooling coil valve, and the heating coil valve during delayed ventilation, occupied/ventilation and unoccupied/shutdown modes.

b. Delivered State: The devices should have been delivered, installed or setup in previous steps so that they are ready to be checked out.

c. Responsibilities: The commissioning personnel are responsible for changing Time Clock settings to change modes of operation, and confirming that the devices perform according to the description given.

d. Adjustment Procedures: Refer to the Time Clock User Manual in the Operation Instruction Booklet for scrolling through the Time Clock settings.

e. Settings: Time Clock settings for the HVAC system operation schedule are listed on the Equipment Schedule.

(1) Occupied/Delayed Ventilation Mode Check

Place the HOA switches for the Supply and Return Fans in the Auto position. Reset the Time Clock (CLK-xx01) so that the system will be in the ventilation delay and occupied mode. Observe that the Vent Delay, Occupied and Fan On pilot lights illuminate, and the Supply and Return fans start. Check that the outside air damper (AD-xx01) and relief damper (AD-xx03) are completely closed and the return air damper (AD-xx02) is fully open. Check that the cooling coil valve (VLV-xx01) and the heating coil valve (VLV-xx02) can be modulated by placing the controllers in the manual mode and varying the controller outputs. If the Economizer is on, place the MAT controller in manual, vary the MAT controller output, and observe that the air dampers do not move. If the Economizer is off, vary the output of the Minimum Position Switch (MPS-xx01) and observe that the air dampers do not move.

(2) Occupied/Ventilation Mode Operation Check

Reset the Time Clock (CLK-xx01) so the system is in the occupied, ventilation mode, and observe that the Vent Delay pilot light turns off. If the Economizer is on, place the MAT controller in manual, vary the MAT controller output, and observe that the air dampers move. If the Economizer is off, vary the output of the Minimum Position Switch (MPS-xx01) and observe that the air dampers move.

(3) Unoccupied Shutdown Check

Reset the Time Clock (CLK-xx01) so that the system will be in the unoccupied mode. Observe that the Occupied and Fan On pilot lights turn off and the fans shut down. If the Economizer is on, place the MAT controller in manual, vary the MAT controller output, and observe that the air dampers do not move. If the Economizer is off, vary the output of the Minimum Position Switch (MPS-xx01) and observe that the air dampers do not move. Place the CDT controller (TC-xx02) in manual, vary the controller output and observe that the cooling coil valve (VLV-xx01) does not move. Place the HDT controller (TC-xx03) in manual, vary the controller output and observe that the heating coil valve (VLV-xx02) moves.

2. CALIBRATION CHECK OF SENSING CIRCUITS

a. General: The circuits that must be checked are the OAT-Economizer controller, RAT, MAT, CDT, HDT, and the OAT-Reset controller. Change the Time Clock Set Times so that the system is in the Occupied, Ventilation mode.

b. Delivered State: Configuration of the controllers in previous steps should have set up the controller to perform properly, thus no adjustments should be required. The temperature transmitter is factory set for the appropriate range, thus no adjustments should be required. Resistive Temperature Detectors (RTDs) are manufactured to give a standard response to different temperatures and require no adjustments.

c. Responsibilities. It is the commissioning personnel's responsibility to confirm that the circuit performs correctly, make any necessary adjustments, and replace any faulty components.

d. Adjustment Procedures: If adjustments or repair are needed for the sensing circuit, follow the procedures located in the Operation and Maintenance Instruction Booklet.

e. Settings: Controller and transmitter ranges and RTD responses can be found in the Operation and Maintenance Instruction Booklets and in the Equipment Schedule sections of the Shop Drawings.

f. Calibration Check: A two-point calibration accuracy check of all HVAC control system sensor/transmitter assemblies shall be performed by comparing the HVAC control-panel readout to the actual value of the temperature measured at the sensor. Digital indicating test instruments shall be used, such as digital thermometers. The test instruments shall be at least twice as accurate as the specified sensor-to-controller readout accuracy. Calibration accuracy checks shall verify that the sensor-to-controller-readout accuracies at the two points are within the specified tolerances. For averaging-temperature sensor-to-controller-readout accuracy checks, (MAT, CDT, and HDT), measurement of the temperature shall be checked every 2 feet along the axis of the sensor, in the proximity of the sensor. A maximum of 10 readings shall be averaged.

(1) Return Air Temperature (RAT) Circuit

General: The components that must be checked or adjusted are: the RAT reading displayed by the Economizer controller (EC-xx01), the RAT transmitter (TT-xx03), and the RAT RTD.

Calibration Check: The RAT is displayed as the Process Variable on the Economizer controller (EC-xx01). Measure the RAT at two different values using a digital thermometer and compare the values to the controller's RAT display.

(2) Economizer Outside Air Temperature (OAT) Circuit

General: The components which must be checked or adjusted are: the OAT reading displayed by the Economizer controller, the OAT transmitter (TT-xx02) and OAT RTD.

Calibration Check: The OAT is displayed as the remote setpoint on the Economizer controller (EC-xx01). Measure the OAT at two different values using a digital thermometer and compare the values to the controller's OAT display.

(3) Mixed Air Temperature (MAT) Circuit

General: The components that must be checked or adjusted are: the MAT reading displayed by the MAT controller, the MAT transmitter (TT-xx01), and MAT RTD.

Calibration Check: The MAT is displayed as the Process Variable on the MAT controller (TC-xx01). Measure the MAT at two different values using a digital thermometer and compare the values to the controller's MAT display.

(4) Cold Deck Temperature (CDT) Circuit

General: The components that must be checked or adjusted are: the CDT reading displayed by the CDT controller, the CDT transmitter (TT-xx04), and CDT RTD.

Calibration Check: The CDT is displayed as the Process Variable on the CDT controller (TC-xx02). Measure the CDT at two different values using a digital thermometer and compare the values to the controller's CDT display.

(5) Hot Deck Temperature (HDT) Circuit

General: The components that must be checked or adjusted are: the HDT reading displayed by the HDT controller, the HDT transmitter (TT-xx05), and HDT RTD.

Calibration Check: The HDT is displayed as the Process Variable on the HDT controller (TC-xx03). Measure the HDT at two different values using a digital thermometer and compare the values to the controller's HDT display.

(6) Hot Deck Reset Outside Air Temperature (OAT) Circuit

General: The components that must be checked or adjusted are: the OAT reading displayed by the OAT controller (TC-xx04), the OAT transmitter (TT-xx02) and OAT RTD.

Calibration Check: The OAT is displayed as the process variable on the OAT controller (TC-xx04). Measure the OAT at two different values using a digital thermometer and compare the values to the controller's OAT display.

3. TUNING OF CONTROLLER

a. General: The controllers that must be tuned and/or operation checked out are: Economizer (EC-xx01), Mixed Air Temperature (TC-xx01), Outside Air Temperature (TC-xx04), Hot Deck Temperature (TC-xx03), and Cold Deck Temperature (TC-xx02). In addition, the Minimum Position Switch (MPS-xx01) needs to be set and the operation of the High Signal Select (TY-xx01) needs to be confirmed.

b. Delivered State: Previous steps should have set up the controllers and other devices so that the control loops are ready for tuning. The MPS-xx01 is not delivered with the correct setting and will have to be set up. The TY-xx01 is factory set to output the high input signal and should require no adjustments.

c. Responsibilities: Commissioning personnel are responsible for tuning the controllers and setting the MPS-xx01 position.

d. Tuning of controllers shall be by the auto (self) tuning feature of the controller unless manual tuning is necessary.

e. Controller Manual-Tuning Procedure: The controller manual-tuning procedure is hereinafter described in three steps using a constant-temperature-setpoint controller as an example.

Step A:

! Index the controller MANUAL/AUTO station to the AUTO position, and set the integral- and derivative-mode constants to zero.

! Set the proportional-mode constant to an initial setting of 8 percent. (This corresponds to 1.5 psig per degree F or 2.0 ma per degree F proportional controller output change for a 100-degree F transmitter span.) This causes the controller output signal to vary from live zero output to full output for an input signal change representing an 8-degree F change.

! Controllers for other variables, such as relative humidity and static pressure, shall have their proportional-mode constants set initially in a similar manner for an achievable output range proportional to the transmitter span.

Step B:

! Set the controller temperature setpoint at any achievable temperature. Observe the controller output and transmitter input.

! If the transmitter input continuously oscillates above and below the setpoint without settling at a fixed value, or if such oscillation increases, the proportional-mode constant is too small.

! If the proportional-mode constant is too small, increase it in steps until the transmitter input indicates stable control at any temperature, provided that the controller output is not at either extreme of the output range.

! If the temperature control point slowly drifts toward or away from the controller setpoint, the proportional-mode constant is too large. Decrease its setting in steps until oscillations occur as described in the preceding paragraphs, and then increase the setting until stable control occurs.

! Introduce a step change in controller setpoint. This should cause the controller to overshoot the setpoint slightly, with each subsequent overshoot peak value decreasing by a factor of 2/3 until stable control is achieved at, above, or below the setpoint.

! Next, increase the integral-mode constant setting in small steps, and introduce setpoint changes until control point and controller setpoint coincide at stable control. This should happen consistently after a setpoint change within a short time, such as 5 to 10 minutes.

Step C:

! Unless the HVAC process variable changes rapidly, the derivative-mode constant setting can remain at zero.

! If derivative control is needed, gradually increase the derivative-mode constant.

! Introduce step changes in controller setpoint, and adjust the derivative-mode constant setting until stable control is achieved.

(1) Minimum Outside Air Check:

Adjustment Procedures: Adjust the Economizer controller so that the Economizer is off. Adjust the Minimum Position Switch (MPS-xx01) until the correct amount of outside air is being introduced. Refer to the Operation and Maintenance Instruction Booklet for instructions on varying the MPS-xx01 output. It is best to perform the check when the OAT is at least 5E F higher than the RAT.

Settings: See the operation and Maintenance Instruction Booklet and/or the Equipment Schedule for the amount of outside air required. The percent of outside air can be determined by the following equation:

PERCENT OA = (MAT - RAT)/(OAT - RAT)

(2) Economizer Operation Check:

Simulate a return air temperature (RAT) greater than the Economizer Process Variable Contact Setpoint (refer to the Equipment Schedule for the setpoint). Simulate an outside air temperature (OAT) equal to or greater than the RAT. Verify that the Economizer light (PL-XX03) is off. Simulate an OAT value equal to or lower than the Economizer Deviation Contact Setpoint. Verify that the Economizer light illuminates and the relief and outside air dampers open fully and the return air dampers close completely. Next, lower the OAT so that its value is at least 4E F lower than the Economizer Process Variable Contact setpoint minus the hysteresis. Then, lower the RAT so that its value is less than the Economizer Process Variable Contact Setpoint, but greater than the Economizer Process Variable Contact Setpoint minus the hysteresis. Observe that the Economizer light remains illuminated.

Increase the OAT and verify that when the OAT rises to a value where the RAT minus the OAT value is less than the Economizer Deviation Contact Setpoint minus the hysteresis value (5E-2E F), the Economizer light turns off, the outdoor and relief air dampers close to their specified minimum positions, and the return air dampers open.

Decrease the OAT so that the Economizer is on. Lower the RAT so that its value is less than the Economizer Process Variable Contact Setpoint minus the hysteresis (75E-2E F). Verify that the Economizer light turns off, the relief and outdoor air dampers go to their minimum positions, and the return air dampers open.

If EMCS is connected to the local control panel, increase the RAT so that the Economizer light turns on, disable (open) the EMCS Economizer Override contact and verify that the Economizer light turns off. Close the contact and verify that the Economizer light turns on. Also verify that an Economizer ON indication is registered at the EMCS through a closed contact of the R-XX07 relay.

(3) Mixed Air Temperature Control Tuning:

Place the MAT controller in the Auto control mode. If the OAT is below the Mixed air temperature (MAT) setpoint (54E F), enact the Automatic tuning feature of the controller and observe the response. The controller will be correctly tuned when the MAT controller (TC-XX01) maintains the MAT to within 0.5E F of the MAT setpoint (54E F).

Otherwise, if the Economizer is on, and the OAT is 10E F or more lower than the RAT, change the MAT setpoint so that it is 2E F higher than the OAT. Enact the Automatic tuning feature of the controller and observe the response. The controller will be correctly tuned when the MAT controller (TC-XX01) maintains the MAT to within 0.5E F of the MAT setpoint (54E F).

(4) Cold Deck Temperature Control Tuning:

Place the CDT controller in the Auto control mode. Place the control system in the Occupied/Ventilation mode. Enact the Automatic tuning feature of the controller and observe the response. The controller will be correctly tuned when the CDT controller (TC-XX02) maintains the CDT to within 0.5E F of the CDT local setpoint (55E F). Perform the tuning when the MAT is between 57E F and 65E F, if possible.

Change the CDT controller to the remote setpoint mode. Input a 20 mA signal to the RSP input terminals and note that the CDT setpoint changes to (60E F). Input a 4 mA signal to the RSP input terminals and note that the CDT setpoint changes to (50E F).

(5) Hot Deck Temperature Control Tuning:

Place the OAT controller (TC-xx04) in the manual mode and adjust the output to 50 percent (12 mA). Place the control system in the Occupied/Ventilation mode. Place the HDT controller in the Auto control mode. Enact the Automatic tuning feature of the controller and observe the response. The controller will be correctly tuned when the HDT controller (TC-XX03) maintains the HDT to within 0.5E F of the HDT setpoint that is displayed.

(6) Reset of Hot Deck Temperature Setpoint:

Simulate three different OAT and verify that for the OAT shown on the OAT controller (TC-xx04), the HDT controller setpoint varies according to the reset schedule shown on the Multizone System Schematic. Simulate OAT at the high end, low end and middle range of the reset schedule.

4. OPERATION OF ALARMS

a. Night Stat Check

General: The components to be checked are: the Night Stat (TSL-xx02).

Delivered State: The Night Stat (TSL-xx02) can be adjusted to activate when the space temperature drops below a specified setting.

Responsibilities: It is the commissioning personnel's responsibility to confirm that the circuit performs correctly and set the setpoint of the Night Stat to the value shown on the drawings.

Adjustment Procedures: Refer to the Operation and Maintenance Instruction Booklet and the Equipment Data Booklet.

Settings: See the Operation and Maintenance Instruction Booklet and/or Equipment Schedule.

Calibration and Operational Check: Reset the Time Clock so that the system is in the Unoccupied mode. Adjust the night thermostat setpoint upward so that the night stat activates. Observe that the Fan On pilot light turns on and the Occupied pilot light remains off. Observe that the supply and return fans start. Place the CDT controller in manual, change the output and observe that the cooling coil valve remains closed. Place the HDT controller in manual, change the output and observe that the heating coil valve modulates. Note that the mixed air dampers have remained in their normal positions. Turn the Night Stat setpoint downward and observe that the HVAC system shuts down. Set the night thermostat setpoint to the specified setting.

b. Smoke Detector

General: The components to be checked are: Smoke Detectors (SMK-xx01) and (SMK-xx02) and the Smoke Alarm relay (R-xx09).
Delivered State: The Smoke Detector is factory set to the appropriate setting and thus no adjustments should be required.

Responsibilities: It is the commissioning personnel's responsibility to confirm that the circuit performs correctly.

Adjustment Procedures: See equipment data booklet.

Settings: See equipment data booklet.

Operational Check: With the HVAC system running, simulate a Smoke Alarm without false-alarming any life safety systems and causing a false fire alarm. Observe that the HVAC system shuts down and the Smoke Alarm Pilot Light turns on. Verify contact output at the EMCS terminals. Reset the fire alarm contacts, note that the Smoke Alarm Pilot Light turns off, but the system does not restart. Press the panel reset button and observe that the HVAC system starts.

c. Low Air Temperature Limit (Freeze Stat)

General: The components to be checked are: the Low Temperature Thermostat (TSL-xx01) and the Low Temperature Alarm relay (R-xx08).

Delivered State: The Low Temperature Thermostat (Freeze Stat) (TSL-xx01) will require setting of the temperature setpoint.

Responsibilities: It is the commissioning personnel's responsibility to confirm that the circuit performs correctly and set the setpoint of the thermostat.

Adjustment Procedures: See equipment data booklet.

Settings: See the Operation and Maintenance Instruction Booklet and Equipment Schedule.

Calibration and Operational Check: With the HVAC system running, simulate a low temperature alarm by increasing the trip setpoint so that an alarm is present. Observe HVAC system shutdown, observe and verify contact output at the EMCS terminal, and observe that the Temperature Alarm Pilot Light turns on. Set the Low Limit Thermostat to the specified setting and press the reset switch on the thermostat, observe that the Temperature Alarm Light turns off, but the HVAC system remains shut down. Press the panel reset button and observe that the HVAC system starts.

d. Filter Alarm

General: The component to be checked is the Filter Differential Pressure Switch (DPS-xx01).

Delivered State: The DPS-xx01 will require setting of the differential setpoint.

Responsibilities: It is the commissioning personnel's responsibility to confirm that the circuit performs correctly and set the setpoint of the switch.

Adjustment Procedures: See equipment data booklet.

Settings: See the Operation and Maintenance Instruction Booklet and Equipment Schedule.

Calibration and Operational Check: With the fan running, in the Occupied mode, simulate a Filter Alarm at DPS-XX01. Verify that the Filter Pilot Light (PL-XX04) illuminates. If EMCS is connected to the local control panel, verify that a filter alarm is registered at the EMCS through a closed contact of DPS-XX01. Restore the filter alarm and verify that the Filter Light turns off.

5. SWITCH CHECKS

a. Enable/Off Switch Operation

General: The component to be checked is the Enable/Off Switch (HS-xx03) in the control panel.

Delivered State: The HS-xx03 is delivered installed in the panel and should require no setup.

Responsibilities: It is the commissioning personnel's responsibility to confirm that the switch works and the HVAC system performs correctly.

Adjustment Procedures: See equipment data booklet.

Calibration and Operational Check: With the fans running, in the Occupied mode, press the Enable/Off switch (HS-XX03) so that the Off Light illuminates and verify that the fans shut down. Press the Enable/Off switch again, verify that the Enable Light illuminates, and the fans turn on.

b. Auto/Override Switch Operation

General: The component to be checked is the Auto/Override Switch (HS-xx01) located in the control panel.

Delivered State: The HS-xx01 is delivered installed in the panel and should require no setup.

Responsibilities: It is the commissioning personnel's responsibility to confirm that the switch works and the HVAC system performs correctly.

Adjustment Procedures: See equipment data booklet.

Calibration and Operational Check: Reset the time clock so that the system is in the Unoccupied mode, and the fans are shut down, press the Auto/Override switch (HS-XX01), verify that the Override light illuminates, the fans turn on and the Occupied Light (PL-XX01) illuminates. Press HS-XX01 so that the Auto Light illuminates. Confirm that the fans turn off.

HAND OPERATING CONDITION

General: The next three sections check the operation of the of the HVAC system when the motor HOA switches are in the Hand position, and confirm that protection systems will shutdown the system if activated.

Delivered State: The devices should have been delivered, installed or setup in previous steps so that they are ready to be checked out.

Responsibilities: The commissioning personnel are responsible for changing Time Clock settings to change modes of operation, and confirming that the devices perform according to the description given.

Adjustment Procedures: Refer to the Time Clock User Manual, located in the Operation Instruction Booklet, for scrolling through the Time Clock settings.

Settings: Time Clock settings for the HVAC system operation schedule are listed on the Equipment Schedule.

1. UNOCCUPIED CONDITION

With the control panel in the Unoccupied mode, place the HOA switch for the Supply Fan Motor Starter in the Hand position, and verify that the Supply Fan starts. Verify that the Cooling Coil valve cannot be modulated by placing the Cold Deck controller in manual, varying the output signal and observing no movement by the actuator. Verify that the air dampers remain in their normal positions.

2. SMOKE DETECTORS

With the fans running and the HOA switch in the Hand position, simulate a smoke alarm. Observe that the fans shut down, the outdoor air dampers close, and the smoke alarm indicator illuminates. Restore the smoke alarm, note that the fans do not start and the smoke alarm indicator turns off. Press the control panel reset button and note that the fan turns on.

3. LOW TEMPERATURE LIMIT

With the fans running and the HOA switch in the Hand position, simulate a Low Temperature Alarm. Observe that the supply fan shuts down, the outdoor air dampers close, and the low temperature alarm indicator illuminates. Restore the Low Temperature alarm, note that the fans do not start and the Low Temperature alarm indicator turns off. Press the control panel reset button and note that the fan turns on.

ZONE DAMPER CONTROL COMMISSIONING

1. ZONE THERMOSTAT SETUP

   a. General: The thermostats for each zone must be set up to control the zone dampers according to the specifications and design.

   b. Delivered State: All thermostats are delivered/installed without being set up.

   c. Responsibilities: The commissioning personnel are responsible for setting up the thermostats.

   d. Adjustment Procedures: Refer to the User Manuals located in the Equipment Data Booklet for information on how to set up each thermostat.

   e. Settings: Settings are listed on the Equipment Schedules and Operation and Maintenance Instructions Booklet.

2. ZONE THERMOSTAT SENSING ACCURACY CHECK

Confirm that the measured temperature of each room where a thermostat is located is within 1° F of the displayed room thermostat temperature.

3. ZONE THERMOSTAT CONTROL OF ZONE DAMPER

a. Low Temperature Operation

Increase the setpoint of each room thermostat so that the difference between the setpoint and actual room temperature is equal to one half of the thermostat's throttling range. Verify that each zone's hot deck dampers move to the wide open position and each zone's cold deck damper moves to the fully closed position.

b. High Temperature Operation

Decrease the setpoint of each room thermostat so that the difference between the actual room temperature and the setpoint is equal to one half of the thermostat's throttling range. Verify that each zone's hot deck dampers move to the fully closed position and each zone's cold deck damper moves to the wide open position.

4. ZONE SETBACK

Confirm that the Zone Thermostat changes the zone's setpoint temperature to the correct value at the appropriate time.

EXPANDED COMMISSIONING REPORT FOR MULTIZONE SYSTEM

OFF/SHUTDOWN CONDITION COMMISSIONING

1. SYSTEM INSPECTION
   a. Supply and Return Fan HOA
      Switches in off position ________________________________
   b. Panel Power on ________________________________
      Main air supplied ________________________________
      Main air gage reading ________________________________
   c. Location of devices correct
      TT-xx01 _
      TI-xx01 ________________________________
      TT-xx02 _
      TI-xx02 ________________________________
      TT-xx03 _
      TI-xx03 ________________________________
      TT-xx04 _
      TI-xx04 ________________________________
      TT-xx05 _
      TI-xx05 ________________________________

DPS-xx01 ____
DPI-xx01 ____
SMK-xx01 ____
SMK-xx02 ____
TSL-xx01 ____
TSL-xx02 ____

d. Damper and Valve check

AD-xx01 closed ___________________________________
AD-xx03 closed ___________________________________
AD-xx02 open ____________________________________
VLV-xx01 closed __________________________________
VLV-xx02 open ___________________________________

e. COMMENTS:

2. SETUP AND CONFIGURATION OF CONTROLLERS
(attach Controller Configuration Checksheets)

a. Economizer (EC-xx01) configured ________________________
b. MAT (TC-xx01) configured ______________________________
c. CDT (TC-xx02) configured ______________________________
d. HDT (TC-xx03) configured ______________________________
e. OAT (TC-xx04) configured ______________________________
f. COMMENTS:

3. SETUP AND CONFIGURATION OF TIME CLOCK
(attach Time Clock Configuration Checksheet)

a. Time Clock (TC-xx01) configured ________________________
b. COMMENTS:

4. ADJUSTMENTS AND CALIBRATION CHECKS OF CONTROLLED DEVICES

(1) MIXED AIR DAMPER CIRCUIT

! Bypass contacts ___________________________________
! TC-xx01 output 0.0% ______________________________
TC-xx01 output 4 mA ______________________________
IP-xx01 output 3 psi _______________________________
AD-xx01 fully closed ______________________________
AD-xx03 fully closed ______________________________
AD-xx02 fully open ________________________________
! TC-xx01 output 100% ______________________________
TC-xx01 output 20 mA _____________________________
IP-xx01 output 15 psi ______________________________
AD-xx01 fully open ________________________________
AD-xx03 fully open ________________________________
AD-xx02 fully closed ______________________________

- ! Remove jumper ____________________
- ! COMMENTS:

(2) COLD DECK VALVE CIRCUIT

- ! Bypass contacts ____________________
- ! TC-xx02 output 0.0% ____________________
  TC-xx02 output 4 mA ____________________
  IP-xx02 output 3 psi ____________________
  VLV-xx01 fully closed ____________________
- ! TC-xx02 output 100% ____________________
  TC-xx02 output 20 mA ____________________
  IP-xx02 output 15 psi ____________________
  VLV-xx01 fully open ____________________
- ! Remove jumper ____________________
- ! COMMENTS:

(3) HOT DECK VALVE CIRCUIT

- ! TC-xx03 output 0.0% ____________________
  TC-xx03 output 4 mA ____________________
  IP-xx03 output 3 psi ____________________
  VLV-xx02 fully open ____________________
- ! TC-xx03 output 100% ____________________
  TC-xx03 output 20 mA ____________________
  IP-xx03 output 15 psi ____________________
  VLV-xx02 fully closed ____________________
- ! COMMENTS:

AUTOMATIC OPERATING CONDITION COMMISSIONING

1. SCHEDULED OPERATING MODES

(1) OCCUPIED/DELAYED VENTILATION MODE CHECK

- ! Supply, Return and Exhaust Fan HOA motor switches in Auto position ____________________
- ! Time Clock statu ____________________
- ! Occupied Light on ____________________
- ! Fan On Light on ____________________
- ! Delayed Vent Light on ____________________
- ! Supply Fan on ____________________
- ! Return Fan in ____________________
- ! AD-xx01 closed ____________________
- ! AD-xx03 closed ____________________
- ! AD-xx02 open ____________________
- ! VLV-xx01 modulation ____________________

- VLV-xx02 modulation ______________________________
- Air Damper modulation ______________________________
- COMMENTS:

(2) OCCUPIED/VENTILATION MODE OPERATION CHECK

- Time Clock status ______________________________
- Delayed Vent Light off ______________________________
- Air Damper modulation ______________________________
- COMMENTS:

(3) UNOCCUPIED SHUTDOWN CHECK

- Time Clock status ______________________________
- Occupied Light off ______________________________
- Fan On light off ______________________________
- Supply Fan off ______________________________
- Return Fan off ______________________________
- Air Damper modulation ______________________________
- VLV-xx01 modulation ______________________________
- VLV-xx02 modulation ______________________________
- COMMENTS:

2. CALIBRATION CHECK OF SENSING CIRCUITS

(1) RETURN AIR TEMPERATURE CIRCUIT

- RAT controller display ______________________________
- RAT measured ______________________________
- RAT controller display ______________________________
- RAT measured ______________________________
- COMMENTS:

(2) ECONOMIZER OUTSIDE AIR TEMPERATURE CIRCUIT

- OAT controller display ______________________________
- OAT measured ______________________________
- OAT controller display ______________________________
- OAT measured ______________________________
- COMMENTS:

(3) MIXED AIR TEMPERATURE CIRCUIT

- MAT controller display ______________________________
- MAT averaged measured ______________________________
- MAT controller display ______________________________

- MAT averaged measured ___________________________
- COMMENTS:

(4) COLD DECK TEMPERATURE CIRCUIT
- CDT controller display _____________________________
- CDT averaged measured ____________________________
- CDT controller display _____________________________
- CDT averaged measured ____________________________
- COMMENTS:

(5) HOT DECK TEMPERATURE CIRCUIT
- HDT controller display _____________________________
- HDT averaged measured ____________________________
- HDT controller display _____________________________
- HDT averaged measured ____________________________
- COMMENTS:

(6) HOT DECK REST OUTSIDE AIR TEMPERATURE CIRCUIT
- OAT controller display _____________________________
- OAT measured ____________________________________
- OAT controller display _____________________________
- OAT measured ____________________________________
- COMMENTS:

3. TUNING OF CONTROLLER
(Note all final P, I, D, and other values on Controller Configuration Checksheets and Equipment Schedules.)

(1) MINIMUM OUTSIDE AIR
- EC-xx01 off ______________________________________
- MPS-xx01 position _________________________________
- OAT ____
- RAT ____
- MAT ____
- %OA ____
- COMMENTS:

(2) ECONOMIZER OPERATION
- PV setpoint ___(F)
  RAT simulated ___(F)
  OAT simulated ___(F)
  Econ light off ___(v)

	DEV setpoint	___(F)
	OAT simulated	___(F)
	Econ light on	___(v)
	OAD and Relief AD open	___(v)
	RAD closed	___(v)
	PV setpoint minus historesis	___(F)
	OAT simulated	___(F)
	RAT simulated	___(F)
	Econ light on	___(v)
!	DEV setpoint minus historesis	___(F)
	OAT simulated	___(F)
	RAT simulated	___(F)
	Econ light on	___(v)
	OAT simulated	___(F)
	Econ light off	___(v)
	OAD and Relief AD minimum	___(v)
	RAD open	___(v)
!	OAT simulated	___(F)
	Econ light on	___(v)
	PV setpoint minus historesis	___(F)
	RAT simulated	___(F)
	Econ light off	___(v)
	OAD and Relief AD minimum	___(v)
	RAD open	___(v)
!	Econ light on	___(v)
	EMCS Econ override disabled	___(v)
	Econ light off	___(v)
	Econ ON registered at EMCS	___(v)
!	COMMENTS:	

(3) MIXED AIR TEMPERATURE CONTROL TUNING

!	OAT displayed	___(F)
	RAT displayed	___(F)
	MAT setpoint	___(F)
	MAT displayed	___(F)
!	COMMENTS:	

(4) COLD DECK TEMPERATURE CONTROL TUNING

!	CDT setpoint	___(F)
	CDT displayed	___(F)
!	TC-xx02 in RSP	_____
	20 mA input to RSP	

CDT setpoint ___(F)
4 mA input to RSP
CDT setpoint ___(F)
! COMMENTS:

(5) HOT DECK TEMPERATURE CONTROL TUNING
! TC-xx04 output 50%
! HDT setpoint ___(F)
HDT displayed ___(F)
! COMMENTS:

(6) REST OF HOT DECK TEMPERATURE
! OAT simulated ___(F)
HDT setpoint ___(F)
OAT simulated ___(F)
HDT setpoint ___(F)
OAT simulated ___(F)
HDT setpoint ___(F)
! COMMENTS:

4. OPERATION OF ALARM

(1) NIGHT THERMOSTAT
! Space temperature ______________________________
! Night Stat setpoint at activation ____________________
! Fan On light status ______________________________
! Occupied light status ____________________________
! Supply Fan on _________________________________
! Return Fan on _________________________________
! VLV-xx01 modulation ___________________________
! VLV-xx02 modulation ___________________________
! Outside Air Damper position ____________________
! Return Air Damper position _____________________
! Relief Air Damper position _____________________
! Night stat deactivated __________________________
! HVAC system status ____________________________
! Final Night Stat setpoint _________________________
! COMMENTS:

(2) SMOKE ALARM
! HVAC system on ________________________________
! Smoke Alarm on ________________________________
! HVAC system off ________________________________

- Smoke Alarm Light on ______________________________
- Fire Alarm off ____________________________________
- Smoke Alarm Light off ______________________________
- HVAC system off __________________________________
- Panel Reset button pressed __________________________
- HVAC system on __________________________________
- COMMENTS:

(3) LOW AIR TEMPERATURE LIMIT/FREEZE STAT ALARM

- HVAC system on __________________________________
- Low Limit Alarm on ________________________________
- HVAC system off __________________________________
- Temperature Alarm Light on _________________________
- Low Limit Alarm off ________________________________
- Temperature Alarm Light off _________________________
- HVAC system off __________________________________
- Panel Reset button pressed __________________________
- HVAC system status ________________________________
- COMMENTS:

(4) FILTER ALARM

- HVAC system on __________________________________
- Filter Alarm on ____________________________________
- HVAC system on __________________________________
- Filter Alarm Light on _______________________________
- Filter Alarm off ____________________________________
- Filter Alarm Light off _______________________________
- COMMENTS:

5. SWITCH CHECKS

(1) ENABLE/OFF SWITCH OPERATION

Fan on ___(v)
Occupied mode ___(v)
Off light illuminated ___(v)
Fan off ___(v)
Enable light illuminated ___(v)
Fan on ___(v)

(2) AUTO/OVERRIDE SWITCH OPERATION

Fan off ___(v)
Unoccupied mode ___(v)
Override light illuminated ___(v)
Fan on ___(v)

Occupied light illuminated ___(v)
Auto light on ___(v)
Fans off

HAND OPERATING CONDITION

1. UNOCCUPIED CONDITION
   Unoccupied mode ___(v)
   Fan off ___(v)
   HAND position ___(v)
   Fan on ___(v)
   No cooling coil modulation ___(v)
   Air dampers in normal positions ___(v)

2. SMOKE DETECTORS
   Fans operating ___(v)
   HAND position ___(v)
   Smoke alarm simulated ___(v)
   Smoke Alarm light on ___(v)
   Fan off ___(v)
   Air dampers to normal positions ___(v)
   Smoke alarm discontinued ___(v)
   Smoke Alarm light off ___(v)
   Fan off ___(v)
   Panel reset button pressed ___(v)
   Fan on ___(v)

3. LOW TEMPERATURE LIMIT
   Fans operating ___(v)
   HAND position ___(v)
   Low temp alarm simulated ___(v)
   Fans off ___(v)
   Low Temp light on ___(v)
   Air dampers to normal positions ___(v)
   Low Temp alarm registered at EMCS ___(v)
   Low temp alarm discontinued ___(v)
   Low Temp light off ___(v)
   Fan off ___(v)
   Panel reset button pressed ___(v)
   Fan on ___(v)

ZONE DAMPER CONTROL COMMISSIONING

1. ZONE THERMOSTAT LOCATION AND SETUP
   (attach Zone Thermostat Configuration Checksheets)
   Zone #x thermostat (T-xxxx) in correct location
   Zone #x thermostat (T-xxxx) set up

2. ZONE THERMOSTAT SENSING ACCURACY

measured zone #x temperature

T-xxxx displayed temperature

3. ZONE THERMOSTAT CONTROL OF ZONE DAMPERS

(1) Low Temperature Zone Damper operation

zone #x setpoint ___(F)

zone #x temperature ___(F)

zone #x throttling range

zone #x hot deck damper open

zone #x cold deck damper closed

(2) High Temperature Zone Damper Operation

zone #x setpoint ___(F)

zone #x temperature ___(F)

zone #x throttling range

zone #x hot deck damper closed

zone #x cold deck damper open

4. ZONE SETBACK

zone #x setback time

zone #x setback setpoint ___(F)

9 TUNING OF SINGLE-LOOP CONTROLLERS

A. BASIC TUNING PRINCIPLES

1. **General**. Tuning of controllers is usually performed as part of the HVAC system commissioning process. Controller tuning is performed after all other devices in the control loop have been adjusted and calibrated and the air and water systems have been balanced. It may also be done subsequent to commissioning if it is found that the controller is not maintaining the control setpoint. This might occur as the system ages and the dynamics of the process change. Some causes of changing process dynamics include: valves getting sticky, scaling of coils, coils getting dirty, and components such as I/Ps going out of calibration. System dynamics also change as a result of changes in environmental conditions. As the inlet air or water temperature to a coil changes, the performance of the control loop changes.

   Tuning the controller consists of selecting the proportional (P), integral (I), and sometimes the derivative (D) mode constants. Proper selection of only the PI-mode constants will usually result in good control. The derivative mode constant can usually be ignored because HVAC processes are relatively slow in their response to system changes. The fastest responding HVAC process is duct static pressure when using a fan speed control device. Yet, even this process can be controlled using only PI-mode constants.

2. **High Versus Low Gain Conditions**. Controllers should always be tuned under high gain conditions. A high gain condition is one in which a small change in controller output results in a large change in the process variable. A good rule to follow is to assume that a low flow or low load condition is a high gain condition.

   An example of this is a heating valve. As the valve first begins to open, its effect on the system's heat transfer rate is greater than when the valve moves from 90 percent to 100 percent open. This effect is illustrated in Figure 9-1 for a heating coil in a duct. With the valve closed, the discharge air temperature is 70E F. After the valve moves to 10 percent open, the steady state temperature of the air rises to 85E F. Upon moving the valve to 20 percent open, the steady state temperature rises to 93E F. In this region of valve operation, the gain is 8E F per 10 percent of valve movement. This gain is much higher than that when the valve is nearly fully open. Note that as the valve moves from 90 percent to 100 percent open, the gain is only about 1E F per 10 percent of valve movement. The steady state, open loop response shown in Figure 9-1 is an extreme example. Response characteristics will vary between different valves and even for a given model of valve depending on how well the valve is matched to its coil. In general, however, the gain of a valve will always be highest at low flow conditions.

   Another example of high and low gain is seen with duct static pressure control. In a lightly loaded variable air volume system with all zone dampers closed to their minimum ventilation air position, there is very little air flow. Under these conditions, a 50 percent change in position of the fan inlet guide vanes might result in a change in duct static pressure of 1 inch of water gauge. In comparison, with all zone dampers open, a 50 percent change of position of the fan inlet guide vanes will result in a smaller change in duct static pressure. The latter is a low gain condition.

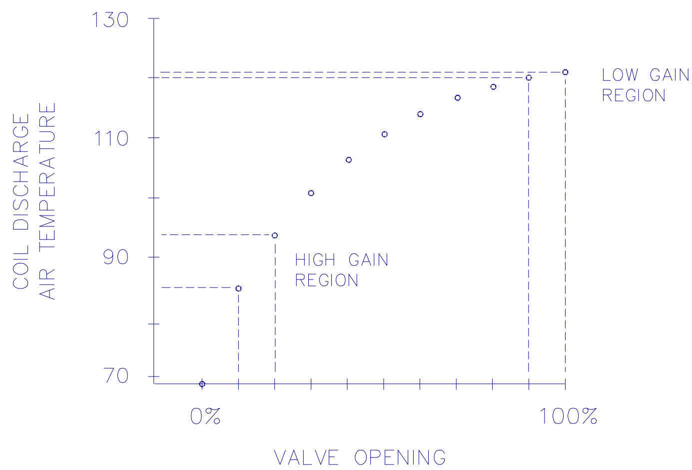

FIGURE 9-1. HIGH AND LOW GAIN CONDITIONS.

3. **Tuning Procedure.** Although there are quantitative methods available for tuning control loops, experience has shown that trial and error is probably the most popular and effective way to tune a control loop. CEGS 15950 describes one method for manually tuning a control loop. It is summarized here:

   a. Establish a high gain condition.

   b. Select an initial proportional band. Use 8 percent for a temperature control process, 20 percent for a humidity control process, and 150 percent for static pressure and return fan volume control processes. Set the I-mode constant to zero if its units are repeats per minute. If the I-mode constant's units are seconds or seconds per repeat, set the I-mode constant to off or to its maximum value. Set the D-mode constant to off or zero.

   c. Reset the setpoint of the controller to some achievable value. For heating or humidity control processes, the setpoint should be raised. Lower the setpoint for a cooling process. Increase or decrease the setpoint for fan control or for mixed air temperature control processes.

   d. Observe the response of the process variable. The peak-to-peak height of the second oscillation should be about one-third the peak-to-peak height of the first oscillation. If the peak-to-peak height of the second oscillation is greater than one-third the height of the first, increase the proportional band setting. If it is less than one-third, decrease the proportional band setting. Initial changes of the proportional band setting should be at least 50 percent of its value. Repeat Steps c and d until the proper peak-to-peak height of the second oscillation is achieved.

e. Increase the integral mode constant setting slightly. (Note: Increase if the units are repeats per minute. Decrease from maximum if the units are seconds or seconds per repeat.)

f. Change the controller setpoint to an achievable setpoint. (Refer to Step c.)

g. Observe the response of the process variable. It should settle out within 5 percent of the new setpoint with little or no overshoot within a reasonable amount of time. For duct static pressure or return fan volume control processes, the settling time should be less than a minute. For humidity or temperature control processes, the settling time should be less than 5 minutes. Repeat Step e until the response is acceptable.

h. Verify the response under high gain conditions.

B. SELF-TUNING SINGLE-LOOP DIGITAL CONTROLLERS (SLDCs)

1. **Types of Self-Tuning SLDCs.** Self-tuning is a process used by SLDCs to automatically select optimal proportional, integral and derivative control mode constants. Two basic types of self-tuning controllers are available on the market. Operator-initiated self-tuning controllers self-tune upon command from an operator. Automatic self-tuning controllers automatically self-tune either continuously or when they determine that the process needs to be retuned. Automatic self-tuning controllers (sometimes called adaptive controllers) are not recommended for use in standard HVAC control applications, primarily because they are not readily available, but also because their performance is questionable and needs further study. An exception to this restriction is made for continuously self-tuning controllers that allow the user to disable the self-tune feature after self-tuning is complete.

2. **Self-Tuning Algorithm Classification.** The self-tuning algorithms used by most SLDCs fall into one of two classifications. The Pattern Recognition Method is the most common classification. The Process Identification Method is another. The Pattern Recognition Method is described by comparing it to the Ziegler-Nichols Process Reaction Curve (PRC) Method, which is a common method of manually tuning a control loop.

   In the PRC method, the controller bumps the process by changing its output control signal to a fixed level as shown in Figure 9-2. It then monitors the change in the process variable in response to this disturbance. This is done while the controller is operating in an open loop (not attempting to control). The controller calculates PID parameters based on measurements of the process variable such as the dead time, time constant, and gain. The dead time (T_d) of a process is the short period of time that the process variable remains unchanged before it begins to move to its new value. Time constant (T_c) indicates the speed of response of a process. These response characteristics are illustrated in Figure 9-3.

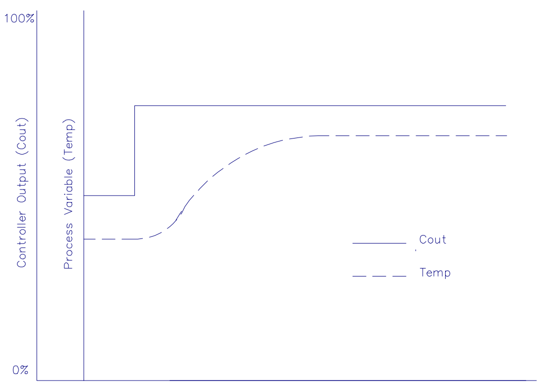

FIGURE 9-2. ZIEGLER-NICHOLS OPEN LOOP PROCESS REACTION CURVE (PRC).

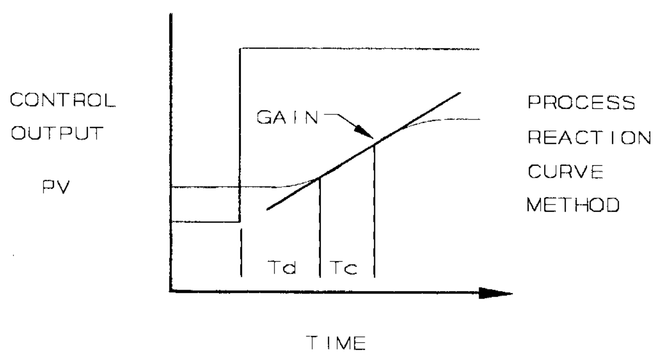

FIGURE: 9-3. PROCESS CRITERIA.

ZIEGLER-NICHOLS REACTION CURVE

Using the Ziegler-Nichols method, the calculated PID parameters result in a quarter-wave damped response to a closed loop setpoint change, as illustrated in Figure 9-4. The controller's setpoint is changed from about 65 to 78E F. The process variable overshoots the setpoint as it begins to settle out. Observe that the peak-to-peak height of the second oscillation of the process variable is one-fourth the peak-to-peak height of the first oscillation. The advantage of this type of response is that the time from the initial setpoint change until the process finally settles out is minimal compared to other types of responses. The disadvantage of this type of response is that it is less stable than a less oscillatory response. Over time, changes in the process dynamics may result in an unstable system.

Pattern recognition self-tuning controllers use an algorithm to replicate this tuning procedure. The exact nature of the algorithm varies from one vendor to the next. Because of these variations in the algorithm, the PID constants used by controllers from different vendors might differ for an identical control loop. For example, one vendor's algorithm might calculate PID values that provide a quarter-wave damped response while another vendor's algorithm might provide a critically damped response (no overshoot of the setpoint). An SLDC using the Process Identification Method monitors the process variable input and controller output signal while the controller is operating in the closed loop control mode. It uses this information to create a mathematical model of the controlled process. Based on this model, the controller either calculates an appropriate control output signal directly or determines appropriate PID values for optimal control. The Process Identification Method is sometimes referred to as adaptive control because it attempts to continuously optimize controller performance. As mentioned previously, self-tuning controllers using this method are not common.

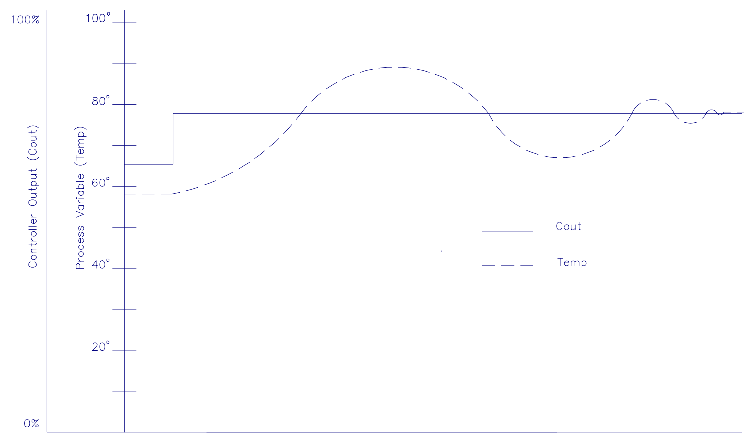

FIGURE 9-4. QUARTER-WAVE DAMPED RESPONSE.

3. **Self-Tuning Experiences.** In a lab test at USACERL's HVAC test facility, an operator-initiated, pattern recognition self-tuning controller was used to tune a hot deck discharge air temperature control system. The self-tuning controller calculated PID values that controlled the process as well as, or better than, the PID values that were selected by a skilled technician during an hour long trial and error attempt at tuning the loop.

In another lab test using the test facility, three different operator-initiated, pattern recognition self-tuning controllers were used to tune a duct static pressure control loop. Each of the controllers successfully self-tuned the loop in less than one minute.

Figure 9-5 illustrates the self-tuning process used by one controller. When the self-tune button is pushed the controller output rises to maximum, drops to minimum, and rises once more to maximum. During this cycling of the output, the controller monitors the process variable (duct static pressure, in this case). Upon completion of self-tuning, the controller calculates PID parameters and automatically returns to closed loop control.

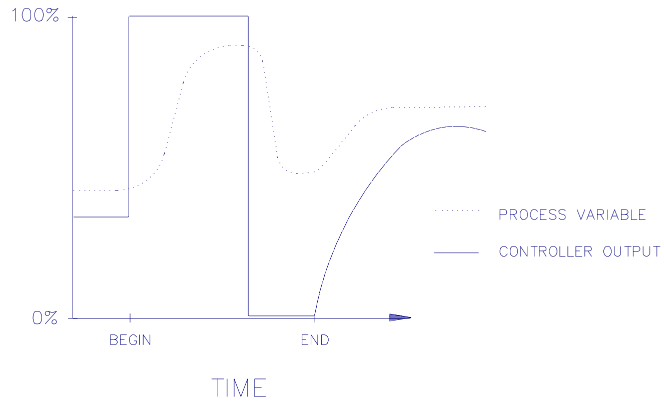

FIGURE 9-5. OPERATOR-INITIATED SELF-TUNE.

Other testing on a variable air volume system at an Army facility showed that each of the controllers tested successfully self-tuned their respective loops. While the resulting closed loop responses were not ideal in some instances, little effort was required to correct these responses to achieve good control.

Variations in self-tuning algorithms indicate that the tuning process is not a generic procedure. One algorithm may work better than another in a given application. In one laboratory test, it was shown that two of the three SLDCs tested could not self-tune to yield satisfactory control of a fan static pressure control system which had a very short time constant of approximately 1 second. This is an extreme case.

4. **Application of Self-Tuning SLDCs.** Although self-tuning can save time and improve control loop performance, caution should be exercised in using the SLDC self-tune feature. The following controllers should not be self-tuned: proportional-only controllers, setpoint reset controllers, or economizer controllers. In PID applications, it cannot be assumed that the controller will always self-tune successfully. In general, if a controller can not be manually tuned to provide satisfactory control, it can not be satisfactorily self-tuned either. Some processes, such as mixed air temperature control, may not lend themselves well to self-tuning. In the mixed air temperature control process, the outdoor air must be cool enough, when mixed with the return air, to cause a fairly significant decrease in the mixed air temperature. If the decrease in mixed air temperature is insufficient, the control loop cannot be manually tuned or self-tuned. As an illustration, assume that a mixed air temperature control loop is tuned under conditions where the outdoor air temperature is 60E F and the return air temperature is 70E F for a temperature difference of 10E F. This approximates the controller throttling range, which means that the controller's output will change from minimum to maximum over a 10E F range. If, at a later time, the outdoor air temperature drops to 50E F while the return air remains at 70E F, the new throttling range becomes 20E F. Since the controller was originally tuned for a 10E F throttling range, it will likely be unstable under the new set of conditions. A small movement of the outdoor air damper will cause a greater change in the mixed air temperature than it would if the outdoor air temperature were only 10E F less than the return air temperature. Therefore the gain of the process is higher under the new condition. As mentioned earlier, control loops should always be tuned under high gain conditions. If tuned

under low gain conditions, the loop may be unstable when the system conditions are such that the gain is high.

Some controllers may require additional configuration information to self-tune successfully. The operator may be required to specify the magnitude of the output signal used to bump the process and to indicate whether or not the process is Afast@ or Aslow.@ Before selecting self-tuning parameters, consult the operator's manual. When in doubt, assume that the process is Afast@ (i.e., responds rapidly to system changes). Also, the maximum output should be set to 100 percent. If there is a minimum output setting, it should be set to 0 percent. An exception to this rule applies to controllers that repeatedly cycle their output during the self-tuning process. Cycling between 0 percent and 100 percent is excessive and may take longer than necessary or be damaging to equipment.

USACERL's experience shows that if self-tuning results in an oscillatory closed loop response, widening the proportional band will help to stabilize the process. Doubling the width of the proportional band is a good rule of thumb.

Some controllers can be configured to filter noise from the process variable input signal. Because filtering should not be necessary in a properly designed and installed system, it is not a Guide Specification requirement. If this feature happens to be available, however, its use may improve self-tuning and control system performance.

10 PERFORMANCE VERIFICATION TESTS

GENERAL

This section deals with the Performance Verification Tests (PVTs) of standard HVAC control systems. The purpose of this section is to describe performance testing of the standard control systems, discuss roles of personnel that are involved in the testing process, and discuss documentation. PVT Procedures and Report for a Multizone HVAC Control System are included at the end of this section. These Procedures contain the level of detail that would be ideal for use in performance verification of the system. They are provided as an example of what is desirable as a submittal from the contractor.

OVERVIEW OF PVT

Performance verification testing is the process of confirming that the control system correctly and accurately controls the HVAC system. The activities conducted during a PVT are generally the same as those conducted during system commissioning, except that devices should not need to be adjusted or calibrated. The PVT is the means by which the Government determines whether it should accept the control system.

PVT RESPONSIBILITIES

Like the commissioning process, performance verification does not simply begin after the system has been installed and commissioned. Rather, it begins at the predesign phase and evolves as the project proceeds from one phase to another. At each phase, details of how the system performance will be verified are added until all the information about how the system operates and performs are included in PVT Procedures and Reports.

To a large extent, the predesign phase of the development of PVT procedures has already been done. Specifications on the content of the Performance Verification Test Procedures and the Performance Verification Test Report are included in Section 1.4 and Section 3.5 of CEGS 15950.

The Designer needs to indicate in the specifications how many copies of the PVT procedures should be submitted by the Contractor. If the project has a building with several identical HVAC control systems, providing six copies of the PVT Procedures for each system is probably not desirable. This would unnecessarily increase the cost of documentation, and may cause a storage problem for the construction personnel and the DPW. One set of six PVT Procedures for each identical type of control system will be sufficient. However, a PVT Report must be provided for each system.

The Contractor is responsible for developing and submitting finalized versions of the PVT procedures, which shall be submitted at least 60 days prior to the planned testing. The Contractor will also be performing the PVT, filling out the PVT report and submitting the PVT report.

The Construction QV personnel are responsible for reviewing the PVT Procedures, notifying the Contractor that he/she may conduct the PVT, attending the PVT, and reviewing and approving the PVT Report.

INTERPRETATION OF CEGS 15950 ON PVT

The PVT must demonstrate that the control system is in compliance with the contract documents (i.e., shop drawings, sequence of operation and specifications). The format of the PVT Procedure is not specified in the Guide Specification, but a recommended structure is as follows:

I. AUTOMATIC OPERATION

- A. Occupied, Unoccupied, and Ventilation-Delay Modes
    1. Startup Check
    2. Vent-Delay Check
    3. Ventilation Check
    4. Shutdown Check

    This section confirms that the Time Clock will start and stop the HVAC system when the AStartup and Shutdown Times@ occur, and will take the system out of the Ventilation-Delay mode of operation. Other items that will be checked are: correct operation of the pilot lights, reasonable time for the HVAC system to come under stable control, and the ability to modulate or not modulate devices, depending on the system mode of operation.

- B. Controller and Sensor Calibration Check

    This section verifies that each sensing loop (sensor, transmitter, and controller) is calibrated or set up correctly.

- C. Control Loop Checks

    The following sections confirm the ability of the controllers to maintain the process at setpoint. The sections also check for correct reset of temperatures, operation of the economizer and correct setting of the minimum outside air.

- D. Alarm Checks

    This section confirms that tripping a temperature, smoke, or other alarm will shut down the system, that the system will remain off until the panel reset button is pressed, and that controlled devices go to and remain in their alarm condition states. This section also checks the operation of the HVAC system when activated by the Night Stat.

II. HAND POSITION OPERATION

- A. Occupied, Unoccupied, Vent-Delay
    1. Unoccupied Operation Check
    2. Occupied Operation Check
- B. Alarm Checks

The PVT Report should follow the format of the PVT Procedures and should include system responses, actions, and values observed or measured during the testing.

The PVT Plans and Procedures (PVT P&P) document is very important and should be thoroughly reviewed by the Designer (A/E or Government) of the system, as well as QV personnel. The PVT P&P not only functions as an approval mechanism of the system, but also aids in maintaining and troubleshooting the control system. A well written, detailed PVT P&P will ensure that the control system conforms with the Sequence of Operation, will check sensor and controller accuracy, and will check for the correct location of devices, such as relay contacts. Finally, a good PVT P&P will allow someone not very proficient in controls to verify the system.

PERFORMANCE VERIFICATION TEST PLANS AND PROCEDURES FOR MULTIZONE SYSTEM

The purpose of these checks is to verify that the Multizone HVAC system performs in accordance with the Sequence Of Operation, maintains stable control of each process at its setpoint, and verify the accuracy of sensing and controlling equipment.

MOTOR H-O-A SWITCH - AUTOMATIC OPERATION

1. Preliminary Setup

_____a. Set the motor Hand-Off-Auto (HOA) switches (M01 and M02) to the Auto position.

_____b. Place the control panel in the Auto mode by pressing the Auto/Override button (HS-XX01), so that the Auto pilot light is illuminated.

_____c. Place the control panel in the Enable mode by pressing the Enable/Off button (HS-XX03), so that the Enable pilot light is illuminated.

_____d. If EMCS is connected to the local control panel, disable any EMCS signals so that the local control panel has complete control of the HVAC system.

2. Occupied, Unoccupied, and Ventilation-Delay Modes of Operation Check

_____a. Refer to the Control System Equipment Schedule for the Time Clock (CLK-XX01) schedule. Verify that the time clock schedule agrees with the Control System Equipment Schedule values.

_____b. Assuming that the system is operating, adjust the Time Clock's time-of-day so that it reads 1 minute before the specified Unoccupied-mode (shutdown) time. When the time-of-day reaches the specified Shutdown time, verify that the Occupied light (PL-XX01) turns off, and Supply Fan (SF-XX01) and Return Fan (RF-xx01) shut down. Verify that the air dampers (AD-XX01, AD-XX02, AD-XX03) move to their normal positions, and cannot be modulated by placing the Economizer (EC-XX01) in the On mode, placing the Mixed Air Temperature Controller (TC-XX02) in manual, and varying the output signal. Verify that the cooling coil valve (VLV-XX01) moves to its normally closed position, and cannot be modulated by placing the Cold Deck Temperature controller (TC-XX02) in manual and adjusting the output. Verify that the heating coil valve (VLV-XX02) can be modulated by placing the Hot Deck Temperature Controller (TC-XX03) in manual and adjusting the output.

_____c. If EMCS is connected to the local control panel, Enable (close) the EMCS Occupied contact and verify that the Occupied pilot light illuminates and the Supply Fan starts. Disable (open) the EMCS Occupied contact and verify that the Supply Fan shuts down.

_____d. Adjust the Time Clock's time-of-day so that it reads 1 minute before the start of the Ventilation Delay mode. When the time of day reaches the specified Ventilation Delay time, verify that the Vent Delay light (PL-XX02) illuminates. When the time-of-day reaches the specified Occupied mode time, verify that the Occupied Light (PL-XX01) illuminates, and the Supply Fan (SF-XX01) begins to run. Verify that the Air Dampers remain in their normal positions. Verify that the cooling coil valve (VLV-XX01) can be modulated by placing the Cold Deck Temperature controller (TC-XX02) in manual and adjusting the output.

_____e. Adjust the time clock's time-of-day so that it reads 1 minute before the end of the Ventilation Delay mode. When the time-of-day reaches the specified end of the Ventilation Delay mode, verify that the Vent Delay light turns off. Verify that the air dampers can be modulated by adjusting the Minimum Outside Air switch (MPS-XX01) signal, or if an Economizer pilot light (PL-XX03) is illuminated, observe that the outside, return, and relief air dampers can be modulated.

_____f. If EMCS is connected to the local control panel, Enable the EMCS Vent Delay contact and verify that the Vent Delay pilot light illuminates and the air dampers move to their normal positions. Disable the EMCS Vent Delay contact and verify that the air dampers move.

3. Controller and Sensor Calibration

These checks should be performed with the system in the occupied mode.

_____a. Verify that the measured temperature of the mixed air is within 1E F of the process variable of the Mixed Air Temperature controller (TC-XX01).

_____b. Verify that the measured temperature of the outdoor air is within 1E F of the remote setpoint of the Economizer controller (EC-XX01).

_____c. Verify that the measured temperature of the outdoor air is within 1E F of the process variable of the Outside Air Temperature controller (TC-XX04).

_____d. Verify that the measured temperature of the return air is within 1E F of the process variable of the Economizer controller (EC-XX01).

_____e. Verify that the measured temperature of the cold deck air is within 1E F of the process variable of the Cold Deck Air Temperature controller (TC-XX02)

_____f. Verify that the measured temperature of the hot deck air is within 1E F of the process variable of the Hot Deck Air Temperature controller (TC-XX03).

4. Minimum Outdoor Air Check

_____a. Refer to the Equipment Schedule for the minimum outside air setting. With the Economizer light off, verify that the air dampers are in the correct positions by confirming that the Mixed Air Temperature (MAT) is within 1E F of the value obtained from the following equation. MAT = %OA * (OAT-RAT) + RAT (Where %OA = the minimum outside air volumetric flow rate, in cfm, divided by the total volumetric air flow rate of the system.) Perform the test when the OAT is 5E F or more above the RAT.

5. Economizer Operation Check

_____a. Simulate a RAT greater than the Economizer Process Variable Contact Setpoint (refer to the Equipment Schedule for the setpoint). Simulate an outside air temperature (OAT) equal to or greater than the RAT. Verify that the Economizer light (PL-XX03) is off. Simulate an OAT value equal to or lower than the Economizer Deviation Contact Setpoint. Verify that the Economizer light illuminates and the relief and outside air dampers open fully and the return air dampers close completely. Next, lower the OAT so that its value is at least 4E F lower than the Economizer Process Variable Contact setpoint minus the historesis. Then, lower the RAT so that its value is less than the Economizer Process Variable Contact Setpoint, but greater than the Economizer Process Variable Contact Setpoint minus the historesis. Observe that the Economizer light remains illuminated.

_____b. Increase the OAT and verify that when the OAT rises to a value where the RAT minus the OAT value is less than the Economizer Deviation Contact Setpoint minus the historesis value (5E F - 2E F), the Economizer light turns off, the outdoor and relief air dampers close to their specified minimum positions and the return air dampers open.

_____c. Decrease the OAT so that the Economizer is on. Lower the RAT so that its value is less than the Economizer Process Variable Contact Setpoint minus the historesis (75E F - 2E F). Verify that the Economizer light turns off, the relief and outdoor air dampers go to their minimum positions and the return air dampers open.

_____d. If EMCS is connected to the local control panel, increase the RAT so that the Economizer light turns on, disable (open) the EMCS Economizer Override contact and verify that the Economizer light turns off. Close the contact and verify that the Economizer light turns on. Also verify that an Economizer ON indication is registered at the EMCS through a closed contact of the R-XX07 relay.

6. Mixed Air Temperature Control

_____a. If the OAT is below the MAT setpoint (54E F) verify that the MAT controller (TC-XX01) maintains the MAT to within 0.5E F of the MAT setpoint (54E F). Change the setpoint of the MAT controller by 5E F and verify that the MAT is brought under stable control at the new setpoint within 5 minutes.

_____b. Otherwise, if the Economizer is on, and the OAT is 10E F or more lower than the RAT, change the MAT setpoint so that it is 2E F higher than the OAT. Then verify that the mixed air temperature is brought under stable control at the new setpoint within 5 minutes.

7. Cold Deck Temperature Control

_____ When in the occupied mode, verify that the Cold Deck Temperature (CDT) controller (TC-XX02) maintains the CDT to within 0.5E F of the setpoint (54E F). Change the CDT setpoint by 5E F and verify that the CDT is brought under stable control at the new setpoint within 5 minutes. Return the CDT setpoint to its original value.

8. Outside Air Temperature Control (Hot Deck Setpoint Reset)

_____ Simulate three different OAT and verify that the Hot Deck Temperature (HDT) setpoint shown on the HDT controller (TC-XX03) varies according to the reset schedule as shown on the Multizone System Schematic. Simulate outside air temperatures at the high, low, and middle range of the transmitter.

9. Hot Deck Temperature Control

_____ Verify that the HDT controller (TC-XX03) maintains the HDT to within 0.5E F of the setpoint. By simulating an OAT, change the HDT setpoint by 5E F and verify that the is brought under stable control at the new setpoint within 5 minutes.

10. Filter Alarm, Low Temperature Alarm, Smoke Alarms, and Night Thermostat

_____a. With the fans running in the Occupied mode, simulate a Filter Alarm at DPS-XX01. Verify that the Filter Pilot Light (PL-XX04) illuminates. If EMCS is connected to the local control panel, verify that a filter alarm is registered at the EMCS through a closed contact of DPS-XX01. Restore the filter alarm and verify that the Filter Pilot Light turns off.

_____b. With the fans running in the Occupied mode, simulate a Low Temperature alarm at TSL-XX01. Verify that the fans shut down, the outdoor air dampers close, and the Low Temperature Alarm Pilot Light (PL-XX05) illuminates. If EMCS is connected to the local control panel, verify that a Low Temperature Alarm is registered at the EMCS through a closed contact of R-XX08. Restore the Temperature alarm contacts to their normal condition, note that the fans do not start and the Low Temperature Alarm Pilot Light turns off. Press the control panel reset button and note that the fans turn on.

_____c. With the fans running and the panel in the Occupied mode, simulate smoke alarms (Do not actually cause a Fire Alarm Signal to be sent. The best way to simulate a smoke alarm is to place a jumper across the control panel terminals where the Smoke Detector Contacts (SMK-XX01 or SMK-XX02) are connected.) Verify that the Smoke Alarm Pilot Light (R-XX09) illuminates, the fans shut down, and the outdoor air dampers close. If EMCS is connected to the local control panel, verify that a smoke alarm is registered at the EMCS through a closed contact of the R-XX09 relay. Reset the smoke alarms, note that the fans do not start and the Smoke Alarm Pilot Light turns off. Press the control panel reset button and note that the fans start.

_____d. With the panel in the Unoccupied mode and the fans shut down, simulate a contact closure at the night thermostat (TSL-XX02). Verify that the supply fans start, that the air dampers remain in their normal positions, and that the Cooling Coil Valve remains closed.

11. Auto/Override and Enable/Off Switch Checks

_____a. With the fans running, in the Occupied mode, press the Enable/Off switch (HS-XX03) so that the Off Light illuminates and verify that the fans shut down. Press the Enable/Off switch again, verify that the Enable Light illuminates, and the fans turn on.

_____b. Change the time of day on the time clock so that the system is in the Unoccupied mode, and the fans are shut down, press the Auto/Override switch (HS-XX01), verify that the Override light illuminates, the fans turn on and the occupied light (PL-XX01) illuminates. Press HS-XX01 so that the Auto light illuminates.

MOTOR H-O-A SWITCH - HAND POSITION OPERATION

1. Occupied, Unoccupied, and Delayed Ventilation Modes of Operation

_____ With the control panel in the Unoccupied mode, place the HOA switch for the Supply and Return Fan Motor Starters in the Hand position, and verify that the fans start. Verify that the Cooling Coil valve cannot be modulated by placing the Cold Deck controller in manual, varying the output signal and observing no movement by the cooling coil actuator. Verify that the air dampers remain in their normal positions.

2. Low Temperature and Smoke Alarms.

_____a. With the fans running and the HOA switch in the Hand position, simulate a smoke alarm. Observe that the fans shut down, the outdoor air dampers close, and the smoke alarm indicator illuminates. Restore the smoke alarm, note that the fans do not start and the Smoke alarm indicator turns off. Press the control panel reset button and note that the fans turn on.

_____b. With the fans running and the HOA switch in the Hand position, simulate a Low Temperature Alarm. Observe that the fans shut down, the outdoor air dampers close, and the low temperature alarm indicator illuminates. Restore the Low Temperature alarm, note that the fans do not start and the Low Temperature alarm indicator turns off. Press the control panel reset button and note that the fans turn on.

MOTOR H-O-A SWITCH - OFF POSITION

_____ With the panel in the Occupied mode, the Vent Delay light off, the HOA Switch in the Auto position, and the fans operating, move the HOA Switch to the OFF position. Verify that the fans shut down, and the air dampers cannot be modulated.

ZONE DAMPER CONTROL

1. Room Thermostat Accuracy Check

_____ Verify that the measured temperature of each room where a thermostat is located is within 1E F of the displayed room thermostat temperature.

2. Room Thermostat Control of Zone Dampers

_____a. Verify that each room thermostat maintains the room temperature within 2E F of the thermostat setpoint.

_____b. Verify that each room thermostat gradually opens the zone's hot deck damper and gradually closes the zone's cold deck damper upon a drop in room temperature, or gradually closes the zone's hot deck damper and gradually opens the zone's cold deck damper upon a rise in room temperature.

_____c. Increase the setpoint of each room thermostat so that the difference between the setpoint and actual room temperature is equal to one half of the thermostat's throttling range. Verify that each zone's hot deck dampers move to the wide open position and each zone's cold deck damper moves to the fully closed position.

_____d. Decrease the setpoint of each room thermostat so that the difference between the actual room temperature and the setpoint is equal to one half of the thermostat's throttling range. Verify that each zone's hot deck dampers move to the fully closed position and each zone's cold deck damper moves to the wide open position.

PERFORMANCE VERIFICATION TEST REPORT FOR MULTIZONE SYSTEM

I. MOTOR HOA SWITCH - AUTOMATIC POSITION

1. Preliminary Setup
   a. HOA Switch in AUTO position ___(v)
   b. Auto Pilot Light illuminated ___(v)

c. Enable Pilot Light illuminated ___(v)
d. EMCS disabled ___(v)

2. Occupied, Unoccupied, and Vent Delay
a. Time Clock Schedule
! Weekday Schedule
Vent Delay ____
Occupied ____
Unoccupied ____
! Weekend Schedule
Vent Delay ____
Occupied ____
Unoccupied ____
! Holiday Schedule
1 ____
2 ____
3 ____
4 ____
5 ____
6 ____
7 ____
8 ____
9 ____
10 ____
11 ____

b. Unoccupied Mode
Occupied Pilot Light Off ___(v)
Fans Off ___(v)
Outside Air Dampers closed ___(v)
Return Air Dampers open ___(v)
Relief Air Dampers closed ___(v)
No modulation of air dampers ___(v)
Cold Deck Valve closed ___(v)
No modulation of Cold Deck valve ___(v)
Hot Deck Valve modulation ___(v)

c. EMCS Occupied Override
EMCS Occupied Override enable ___(v)
Occupied Pilot Light on ___(v)
Fans Start ___(v)
EMCS Occupied Override disabled ___(v)
Occupied Pilot Light off ___(v)
Fans off ___(v)

d. Ventilation Delay Mode
Vent Delay Pilot Light on ___(v)

		Occupied Pilot Light on	___(v)
		Fans on	___(v)
		Outside Air Dampers closed	___(v)
		Return Air Dampers open	___(v)
		Relief Air Dampers closed	___(v)
		Cold Deck Valve modulation	___(v)
	e.	Occupied Mode	
		Vent Delay Pilot Light off	___(v)
		Air Dampers modulation	___(v)
	f.	EMCS Vent Delay Override	
		EMCS Vent Delay Override enable	___(v)
		Vent Delay Pilot Light on	___(v)
		Air Dampers to normal position	___(v)
		EMCS Vent Delay Override disabled	___(v)
		Vent Delay Pilot Light off	___(v)
		Air Damper Modulation	___(v)
3.	Controller and Sensor Calibration		
	a.	MAT measured	___(v)
		MAT controller	___(v)
	b.	OAT measured	___(v)
		OAT controller (ECON)	___(v)
	c.	OAT measured	___(v)
		OAT controller (OAT)	___(v)
	d.	RAT measured	___(v)
		RAT controller	___(v)
	e.	CDT measured	___(v)
		CDT controller	___(v)
	f.	HDT measured	___(v)
		HDT controller	___(v)
4.	Minimum Outdoor Air Check		
		Economizer light off	___(v)
		OAT displayed	___(F)
		RAT displayed	___(F)
		MAT displayed	___(F)
		Min OA cfm setpoint	____
		System cfm	____
		%OA	___(v)
		MAT calculated	___(v)

5. Economizer Operation Check

a.	PV setpoint	___(F)
	RAT simulated	___(F)
	OAT simulated	___(F)
	Econ light off	___(v)
	DEV setpoint	___(F)
	OAT simulated	___(F)
	Econ light on	___(v)
	OAD and Relief AD open	___(v)
	RAD closed	___(v)
	PV setpoint minus historesis	___(F)
	OAT simulated	___(F)
	RAT simulated	___(F)
	Econ light on	___(v)
b.	DEV setpoint minus historesis	___(F)
	OAT simulated	___(F)
	RAT simulated	___(F)
	Econ light on	___(v)
	OAT simulated	___(F)
	Econ light off	___(v)
	OAD and Relief AD minimum	___(v)
	RAD open	___(v)
c.	OAT simulated	___(F)
	Econ light on	___(v)
	PV setpoint minus historesis	___(F)
	RAT simulated	___(F)
	Econ light off	___(v)
	OAD and Relief AD minimum	___(v)
	RAD open	___(v)
d.	Econ light on	___(v)
	EMCS Econ override disabled	___(v)
	Econ light off	___(v)
	Econ ON registered at EMCS	___(v)

6. Mixed Air Temperature Control

a.	OAT displayed	___(F)
	MAT setpoint	___(F)
	MAT displayed	___(F)
	MAT setpoint	___(F)
	MAT displayed	___(F)
	Time to stable control	___(min)
b.	OAT displayed	___(F)
	RAT displayed	___(F)

new MAT setpoint	___(F)
MAT displayed	___(F)
Time to stable control	__(min)

7. Cold Deck Temperature Control

CDT setpoint	___(F)
CDT displayed	___(F)
CDT setpoint	___(F)
CDT displayed	___(F)
Time to stable control	__(min)

8. Outside Air Temperature Control

OAT simulated	___(F)
HDT setpoint	___(F)
OAT simulated	___(F)
HDT setpoint	___(F)
OAT simulated	___(F)
HDT setpoint	___(F)

9. Hot Deck Temperature Control

HDT setpoint	___(F)
HDT displayed	___(F)
HDT setpoint	___(F)
HDT displayed	___(F)
Time to stable control	__(min)

10. Alarms and Night Stat Operation

a. Filter Alarm operation

Fans operating	___(v)
Filter alarm simulated	___(v)
Filter light on	___(v)
Filter alarm registered at EMCS	___(v)

b. Low Temperature Alarm operation

Fans operating	___(v)
Low temp alarm simulated	___(v)
Fans off	___(v)
Low Temp light on	___(v)
Air dampers to normal positions	___(v)
Low Temp alarm registered at EMCS	___(v)
Low temp alarm discontinued	___(v)
Low Temp light off	___(v)
Fans off	___(v)
Panel reset button pressed	___(v)
Fans on	___(v)

c. Smoke Alarm operation

Fans operating	___(v)
Smoke alarm simulated	___(v)
Smoke Alarm light on	___(v)
Fans off	___(v)
Air dampers to normal positions	___(v)
Smoke alarm registered at EMCS	___(v)
Smoke alarm discontinued	___(v)
Smoke Alarm light off	___(v)
Fans off	___(v)
Panel reset button pressed	___(v)
Fans on	___(v)

d. Night Thermostat operation

Fans off	___(v)
Night Stat alarm simulated	___(v)
Fans off	___(v)
Air dampers to normal positions	___(v)
No Cold Deck modulation	___(v)

11. Auto/Override and Enable/Off Switch Checks

a. Enable/Off switch

Fans on	___(v)
Occupied mode	___(v)
Off light illuminated	___(v)
Fans off	___(v)
Enable light illuminated	___(v)
Fans on	___(v)

b. Auto/Override switch

Fans off	___(v)
Unoccupied mode	___(v)
Override light illuminated	___(v)
Fans on	___(v)
Occupied light illuminated	___(v)
Auto light on	___(v)

II. MOTOR HOA SWITCH - HAND POSITION

1. Occupied, Unoccupied and Vent Delay

Unoccupied mode	___(v)
Fans off	___(v)
HAND position	___(v)
Fans on	___(v)
No cooling coil modulation	___(v)
Air dampers in normal positions	___(v)

2. Low Temperature and Smoke Alarm

a. Smoke Alarm operation

Fans operating	___(v)
HAND position	___(v)
Smoke alarm simulated	___(v)
Smoke Alarm light on	___(v)
Fans off	___(v)
Air dampers to normal positions	___(v)
Smoke alarm discontinued	___(v)
Smoke Alarm light off	___(v)
Fans off	___(v)
Panel reset button pressed	___(v)
Fans on	___(v)

b. Low Temperature Alarm operation

Fans operating	___(v)
HAND position	___(v)
Low temp alarm simulated	___(v)
Fans off	___(v)
Low Temp light on	___(v)
Air dampers to normal positions	___(v)
Low Temp alarm registered at EMCS	___(v)
Low temp alarm discontinued	___(v)
Low Temp light off	___(v)
Fans off	___(v)
Panel reset button pressed	___(v)
Fans on	___(v)

III. MOTOR HOA SWITCH - OFF POSITION

Fans operating	___(v)
AUTO position	___(v)
Occupied mode	___(v)
Vent Delay light off	___(v)
Fans on	___(v)
OFF position	___(v)
Fans on	___(v)
Air dampers to normal positions	___(v)

IV. ZONE DAMPER CONTROL

1. Room Sensor Calibration

measured zone #1 temperature	___(v)
displayed thermostat temperature	___(v)
measured zone #2 temperature	___(v)
displayed thermostat temperature	___(v)

measured zone #3 temperature ___(v)
displayed thermostat temperature ___(v)

measured zone #4 temperature ___(v)
displayed thermostat temperature ___(v)

measured zone #5 temperature ___(v)
displayed thermostat temperature ___(v)

2. Cold Deck Temperature Control

a. zone #1 setpoint ___(F)
zone temperature ___(F)

zone #2 setpoint ___(F)
zone temperature ___(F)

zone #3 setpoint ___(F)
zone temperature ___(F)

zone #4 setpoint ___(F)
zone temperature ___(F)

zone #5 setpoint ___(F)
zone temperature ___(F)

b. zone #1 setpoint ___(F)
zone temperature ___(F)
throttling range ___(F)
zone hot deck dampers open ___(F)
zone cold deck dampers closed ___(F)

zone #2 setpoint ___(F)
zone temperature ___(F)
throttling range ___(F)
zone hot deck dampers open ___(F)
zone cold deck dampers closed ___(F)

zone #3 setpoint ___(F)
zone temperature ___(F)
throttling range ___(F)
zone hot deck dampers open ___(F)
zone cold deck dampers closed ___(F)

zone #4 setpoint ___(F)
zone temperature ___(F)
throttling range ___(F)

zone hot deck dampers open ___(F)
zone cold deck dampers closed ___(F)

zone #5 setpoint ___(F)
zone temperature ___(F)
throttling range ___(F)
zone hot deck dampers open ___(F)
zone cold deck dampers closed ___(F)

c. zone #1 setpoint ___(F)
zone temperature ___(F)
throttling range ___(F)
zone hot deck dampers closed ___(F)
zone cold deck dampers open ___(F)

zone #2 setpoint ___(F)
zone temperature ___(F)
throttling range ___(F)
zone hot deck dampers closed ___(F)
zone cold deck dampers open ___(F)

zone #3 setpoint ___(F)
zone temperature ___(F)
throttling range ___(F)
zone hot deck dampers closed ___(F)
zone cold deck dampers open ___(F)

zone #4 setpoint ___(F)
zone temperature ___(F)
throttling range ___(F)
zone hot deck dampers closed ___(F)
zone cold deck dampers open ___(F)

zone #5 setpoint ___(F)
zone temperature ___(F)
throttling range ___(F)
zone hot deck dampers closed ___(F)
zone cold deck dampers open ___(F)